UNIVERSIDAD DE GRANADA

Facultad de Ciencias de la Educación

Doctorado en Educación

Línea: *Didáctica de las Ciencias Experimentales y de la Sostenibilidad*

TESIS DOCTORAL

A STUDY OF ELECTRICITY SIXTH GRADE TEXTBOOKS FROM CANADA AND PAKISTAN: STUDENT RESPONSES AND CONTENT ANALYSIS

Realizada por

ALTAF QADEER

Director: **Dr. FRANCISCO JAVIER PERALES PALACIOS**

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Francisco Javier Perales Palacios, Doctor en Ciencias Físicas y Catedrático del Departamento de Didáctica de las Ciencias Experimentales de la Universidad de Granada

En calidad de director de la Tesis Doctoral que lleva por nombre "*A study of electricity sixth grade textbooks from Canada and Pakistan: Student responses and content analysis*", presentada por D. **Altaf Qadeer**

CONSIDERA:

Que reúne los requisitos de interés académico, rigor científico y actualidad documental necesarios para ser presentada a su lectura. Por lo que,

INFORMA favorablemente a la misma, autorizando su presentación con el fin de proceder a su defensa pública.

En Granada, Mayo de 2013.

Fdo. Francisco Javier Perales Palacios

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ABBREVIATIONS

NOS	Nature of science
RNOS	Representatives of the nature of science
HSE	History of science education
NSE	Nature of science education
LED	Light emitting diode
HPS	History and philosophy of science
CI Model	Construction Integration Model
iSTART	Computer program on the comprehension of text
K-12	Kindergarten to grade twelve
STSE	Science, technology, society, and the environment
ERIC	Education resources information centre
CT	Canadian textbook
PT	Pakistani textbook

ABSTRACT

The current study explores the explanatory understanding indicators on the topic of "electricity" in the Grade 6, textbooks of Canada and Pakistan. It examines the occurrence of certain text characteristic features such as types of key-words, sentences and paragraphs (cf. Bublitz et al. 1999; Fraenkel et al. 1993; Newton et al. 2002). This interdisciplinary study combines key-word use, sentence analysis and paragraph analysis to analyze indicators for explanatory understanding. In a previous research study some background is discussed for this analysis in the work of Newton et al. (2002). They counted the frequency of certain clauses in a number of textbooks. One rationale they offered is that there is a lack of concern for explanatory understanding structures found in a textbook. They also emphasized that there is no simple relationship between the two processes (frequency occurrence of clauses versus explanatory understanding). The data is collected through the document analysis and empirical study in Canada and Pakistan. Two groups of students in each study were also given the same textbook to study. The experimental group was given some additional resources to compare the contrast of learning and how explanatory understanding can be improved. The study also explores if the related textbooks provided opportunities for understanding using explanatory sentences. A grade six-level textbook can explain this concept to show more reasoning behind everyday observations (cf. Keil and Wilson 2000) of the concept of electricity.

The presentation of direct results include statistical data from the textbook language structure, lexeme occurrence, sentence analysis, paragraph analysis, student-made pictures, student writing analysis of lexemes, and the multiple choice tests. The indirect results of this study are discussed in relation to the multiple dimensions of various studies conducted on similar topics. Based on those results and discussions, recommendations are made for applying some of the outcomes of this study in textbook designing, curriculum designing, and the general teaching process. The underlying process of learning has many common foundations (cf. Roscoe and Mrazek 2005; Glynn et al. 1991; DeBoer 1991), therefore science learning from textbooks is perhaps comprehensively analyzed when multiple factors are compared within the parameters of a study, and analysis is extended to other similar studies and ground work is presented for future studies.

Science textbooks are used in Canadian and Pakistani elementary level schools for a range of needs (cf. Mahmood 2011; DiGiuseppe 2007). The design of textbooks is a combination of interdisciplinary knowledge and skills, from various fields (cf. Venezky 1992; Purves 1993; Wellington 2001) such as, cognitive science, curriculum theory, psychology, education, science, philosophy, linguistics, technology and other similar domains (Purves 1993; Chambliss and Calfee 1998). The importance of textbooks depends on the user group: teachers rely on textbooks for lessons planning (Mikk 2000:15), students use them frequently i.e. for self-study (Roth 2005:241), and

“the textbook industry is a multi-billion dollar enterprise” (Phillips 2006:iv). The constant changes in curriculum design, policy changes, research paradigm shifts, social and pedagogical aspects make it important to analyze and update textbooks from a variety of frameworks (Chambliss and Calfee 1998; Johnsen 1993; Giordano 2003).

There were two textbooks analyzed for this study on the topic of electricity. One was published in Canada and the other one was published in Pakistan. The Canadian textbook analysed for this study *Electricity—Science & Technology* was published by Addison Wesley, Pearson Education Canada (Campbell et al. 1999) and no detailed textbook is available that is approved by the Ontario Ministry of Education. . The textbook in Pakistan was published by Punjab Textbook Board, Lahore in 2011 (Sleemi et al. 2011). From now on in this research study the Canadian textbook will be referred as “CT” and the Pakistan’s textbook will be referred as “PT”. In fact, the educational research database ERIC shows that there is no study conducted on a science textbook for children in which micro-level and document analysis methods were combined. Thus the present study fills an urgent research gap.

The current study explores the explanatory understanding in the CT and PT and it examines the occurrence of certain text characteristic features such as types of key-words, sentences and paragraphs (cf. Bublitz et al. 1999; Fraenkel et al. 1993; Newton et al. 2002). This interdisciplinary study combines key-word use, sentence analysis and paragraph analysis to analyze indicators for explanatory understanding. The basis for this analysis was given by Newton et al. (2002), they counted the frequency of certain clauses in a number of textbooks. One rationale they offered is that there is a lack of concern for explanatory understanding structures found in a textbook. They also emphasized that there is no simple relationship between the two processes (frequency occurrence of clauses versus explanatory understanding).

The data collected through the document analysis and empirical study indicates that a textbook on the topic of electricity designed for grade six has missed the opportunity of being as explanatory as possible. A grade six-level textbook can explain this concept to show more reasoning behind everyday observations (cf. Keil and Wilson 2000). The general uses of electricity shown in a textbook may not be good enough for constructing explanatory understanding with reference to the flow of electrons. The contents of the textbook are also scrutinized, analyzed and discussed for possible misconceptions for the intended grade six-level students. The research design was comprised of control and experimental groups, to compare the distinction of the results in the two settings. The control group used just the regular textbook (in the respective area of Canada and Pakistan) and the experimental group used the respective textbook (Canada and Pakistan) along with some additional resources.

In many places, the Ontario curriculum expectations work as guide for textbook writing. They are also critically discussed in this study to promote explanatory understanding of science concepts.

This study also includes data on the science textbook of Grade 6 from Pakistan on the topic electricity published by the Punjab Textbook Board, Lahore in 2011. The data collection approach was same as it was for the Canadian textbook. The data shows the textbooks from Pakistan had less emphasis on explanatory understanding. The student responses also indicated lack of explanatory understanding. The use of some additional books with explanatory understanding shows students were able to understand better about the concept of electricity with the help explanatory text and pictures of atoms.

This study shows the need for using more explanatory texts and pictures to facilitate the learning of science students at elementary level, and further studies can extend these research parameters. The main focus of the present study is not on the effects of graphic comprehension - although a classified collection of various types of student-made pictures is included. Despite the lack of standardized textbook analysis methods (cf. Wellington 2001; Purves 1993), the use of more balanced qualitative and quantitative analysis methods to compare curriculum delivered versus curriculum received can provide a variety of data (cf. Chambliss and Calfee 1998). Further research on Canadian and Pakistani textbooks is necessary in order to promote local and international level comparative studies (cf. Roth et al. 2005: vii, Mahmood 2011).

Chapter 1 INTRODUCTION

Various learners learn differently from the same textual and iconic information presented. Presenting science in the form of textbooks to Grade 6 students is a challenging task. The language of science, the complexity of science concepts and the barriers attached to the modes of communication bring various challenges for those who interface in this process.

One of the goals of learning science is to understand the reasons behind certain concepts of science. How effectively elementary level science textbooks present those scientific reasons? This question is something I was thinking about while teaching in Pakistan and Canada. The concept of electricity was taught in both places and students were very excited to learn about it as they would hear about this in everyday life and it also frequently integrated other topics related to science. The student population where I worked for a long time has Grade 6, 7, 8 students. Grade 6 students go through a transition year in some schools as they change their school to a middle school. On the other hand many students in Grade 6 class have to learn new science vocabulary in a challenging academic environment. The use of science textbook has been frequent in those schools in Canada and Pakistan where those observations were made. During my various teaching experiences it was also observed that text and pictures with explanatory component can play an important role in the responses of students. The topic of textbook analysis was also a focus of my previous research. In this research some indicators of ambiguity were explored in the elementary level science textbooks. The idea was further inspired in 2002 by reading an intriguing article by Dr. Perales about the children's responses to TV cartoons for learning science concepts. The research of Dr. Perales also opened doors to think further about it and to collect data with the multiple applications of learning resources from various geographical locations. With many years of teaching language, math, science and other subjects it became an interesting point to research on the elementary level science textbook explanations and the students' responses. The other research avenue to explore relates to the learning resources with extensive explanatory component related to science concepts and the extent it facilitate students' learning. With those multi-faceted experiences and observations it became a topic of interest to research further on the textbook along with student responses from the two countries where I taught. The findings may be useful in some way to improve science learning in those schools.

Children science learning has multiple epistemic and ontological aspects, from the interplay of contents to pedagogy and from the nature of science to the nature of education, many aspects play an important role (cf. Rosenbaltt 2011; Kuhn 2010; Perales and Vilchez 2002). Current trends in science education for children emphasize on explanatory understanding (cf. Newton et al. 2002) developing critical habits of mind (cf. Rosenbaltt 2011), developing explanation and argument skills (cf. Osborne et al. 2011), from conceptualization to explanatory unification for extended conceptual links (cf. Braaten et al. 2011), and engaging in scientific discourse (Kuhn 2010). Among many avenues and resources applied to meet such high level goals, children science textbooks are one of them, yet they are very important aspect of the learning environment (cf. Mikk 2000; Roth 2005).

Textbooks have been a part of human learning culture since writing and schooling has existed. However, formats such as clay tablets, sheets of papyrus or other forms have varied (cf. Farrell 2003). The word 'text' comes from Latin, which means 'inter-woven' (cf. Piller 2005). The notion of text can also refer to words weaving in a specific way. With the invention of the printing press, textbook publishing has increased in many parts of the world. According to Purves (1993:13) "*Orbis Pictus of Comenius* is frequently mentioned as among the first illustrated school texts, but it was preceded by many with and without illustration." The textbook industry has gone through many trends of acceptance and critics. The trends in favor and against the textbooks include: business related decision making in terms of cost and affordability, war time political standpoints in the textbooks, racial themes and language sensitivity, gender oriented approaches, religious viewpoints, research paradigm shifts, learning effectiveness and technological challenges (cf. Giordano 2003; Mintzes, Wandersee, and Novak 1998). The demand for the textbook has constantly urged publishers to accommodate the concerns of relevant groups. Despite the predictions of textbook elimination, textbooks are still surviving in classrooms (Giordano 2003). Textbooks have incorporated a number of demands from critics, and this is an ongoing process that keeps the new textbooks published with the inclusion of new demands. Overall, the textbook is an easily available learning tool in many parts of the world and therefore it has maintained a crucial place in the learning environment (Giordano 2003; Farrell 2003). A very common goal of science literacy is to encompass various aspects of science and its use in our society (Reeves 2005).

Elementary level science textbooks aim to inform the readers in a simplified way along with addressing curriculum expectations. The designing of science textbooks is also influenced by the science curriculum or *curriculum expectations* of a local system. Wellington (2001:71) remarks: "The introduction of science in the school curriculum of the nineteenth century entailed the writing of syllabuses and schemes of work." In the current educational systems, the writing of curriculum expectations and the designing of textbooks have close links in some provinces or school boards.

Much has been written about the strategies for science teaching to middle school students and textbook is an important part of the learning environment. According to Driscoll, Moallem, Dick and Kirby (1994:98):

> For the textbook to play a more effective role in supporting active knowledge construction, it should be conceived as part of a total instructional system, where the role of each component in the system is identified. The textbook may, for example, suggest sources of information to study or be tied into a larger database. It may suggest exploration strategies or contain worked out examples. It may become a handbook

> more than a textbook. Certainly, to effectively support knowledge construction in a reasoned way, it must present multiple perspectives on a topic rather than authoritatively stated, bald facts. Whatever the future role of textbooks, however, we must consider what goals are considered desirable for learning and how these may best be facilitated. We must also consider how best to facilitate teachers' understanding of the roles textbooks can play in instruction.

The value of the textbook as a learning tool has been analyzed in many previous studies to explore clause frequencies, the balance for the themes of the nature of science, learning patterns, and historical perspectives (Newton et al. 2002; Phillips 2006; Maxell 1926; Chall and Conard 1991; Wellington 2001). Mikk (2000:25) states the rationale "the evaluation of textbooks means the assessment of correspondence between the characteristics of a textbook and the ideal set of characteristics." Based on this need the evaluation of textbooks remains an ongoing task for the future research studies.

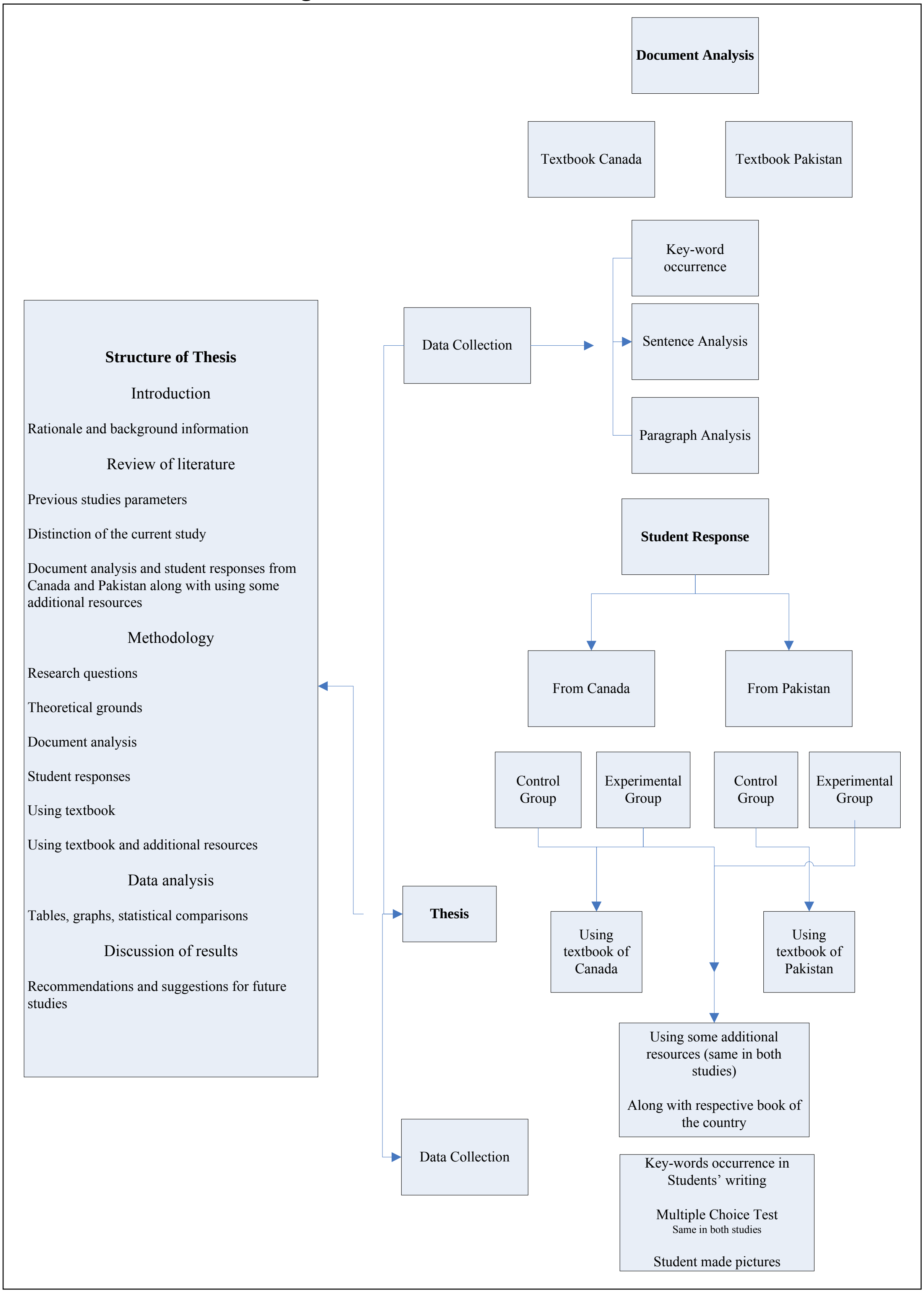
Chapter two of this text dwells on the review of the relevant literature to this study from a multiple perspective. Studies conducted on textbook analysis, science education, concept formation of science ideas, curriculum analysis, nature of science factors, curricular models of the real structures and expert review of the textbooks will be discussed.

Chapter three discusses the critical reasons for data collection background strategies, education research methods and their relevance to this study, rationale to the frameworks of study designed, and the limitation of this study.

Chapters four presents the data collected, and analyze various qualitative and quantitative factors from the study specific dimensions. Discussion is provided to further elucidate the results and make connections to other relevant studies.

Chapter five aims to present the findings and conclusions of this study with some recommendations based on the direct and indirect results within the parameters of specific variables. This chapter also provides the significance of this study and the implications for developing and analyzing learning resources. The limitations to apply the results of this study are also discussed to make detailed comparisons of this study and consider future studies. The conclusions in this chapter are comprised of recommendations and suggestions for further research studies on textbook analysis in Canada or other parts of the world.

Figure 1: The structure of thesis



1.1. Trends in science education and their reflections in the textbooks

The trends in science education have gone through many changes, and it is still an on-going process. Science education has influences of various related paradigms of research. Some important eras include practicalist, academic, and human constructivist (Mintzes, Wandersee, and Novak 1998).

The practicalist era is considered around 1918 to 1957. The practicalist trend includes theorists such as Dewey, Thorndike, Binet, Cubberley, Terman and others. The focus of research issues during this era was on improving efficiency and applied skills. The philosophical focus of that time was more on rationality. Research designs of that era included descriptive surveys, and some partial form of experimental designs.

The academic era is considered around 1958 to 1977. The academic trend includes theorists such as Piaget, Ausubel, Bruner and others. The focus of research issues during this era was on the questions of scientific inquiry, change of behaviour, and the developmental stages. The philosophical focus of this era was on empirical and behaviour changes. The research designs at that time focused on common scientific laws, correlation studies, and some experimental designs (Mintzes, Wandersee, and Novak 1998).

The human constructivist era is considered around 1978 onwards. The human constructivist trend included theorists such as Novak, Vygotsky, and Kuhn. During this era the focus of research issues has been more on the meaningfulness, understanding concepts, change in concepts and knowledge structure. The philosophical focus of this era has been on the constructivist approaches. The research designs of this timeframe include cognitive analysis, case studies, and concept base descriptions (Mintzes, Wandersee, and Novak 1998).

The textbooks of corresponding eras have reflected the specific trends of science education in many ways. Some examples of reflecting science education research patterns in the science textbooks are: the designing of textbooks with intense applied work; stimulus response situations; finding errors in understanding cognitive patterns; and student centered designs for problem solving.

In the recent trends science textbooks have extended links to other subjects of schools as Newton et al. (1999:556) remarks:

> Science education also has an important contribution to make to the general education of students by developing their ability to understand, construct and evaluate arguments (both as individuals and as contributors to a group).

The discussion of socio-scientific issues also plays an important role in this context. Students learn to form opinions based on scientific reasoning, for example impact of the environment issues in social life (Newton et al. 1999).

1.1.2. The designing cost and the life of textbooks

Textbook designing is a lengthy and costly process. A major target of the publishing companies is to make earnings from the investment. The ongoing changes in the curriculum, research interest shifts, and policy changes become the catalyst for textbook changes. According to Purves (1993:15), “the textbook takes about two years to produce—although desk- top publishing can shorten the process somewhat. In many schools, the life of a textbook is about five years.”

In many cases, the work for the next textbook is started shortly after the publication of the first one. Nevertheless, various economic challenges, geographical difficulties, and political aspects can alter those practices. The publisher’s strategies to cope with those changes include constantly accommodating modifications wherever possible or necessary. With the availability of computer-based tools, it is easy to compile the textbook and save the information, while the hardcopy publishing can be adjusted according to the changing demand of the users.

1.2. The importance of communication between the researchers and the textbook designers

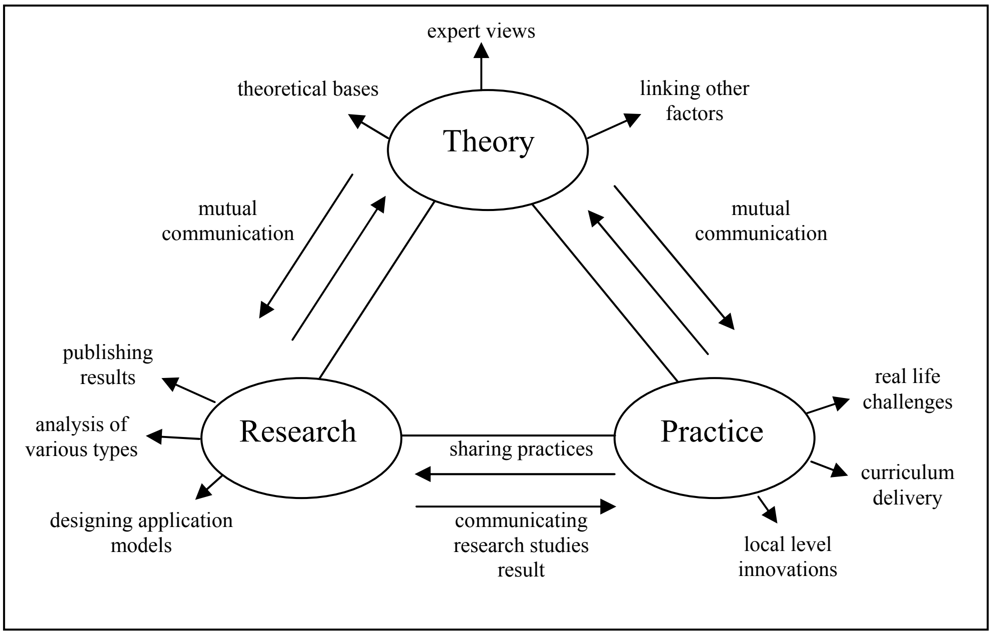
Purves (1993:17) has described textbook patterns as follows:

> Textbooks are indeed a kaleidoscope, and we should not see them as being a single image or even a single refraction of the light of instruction. How we view them depends on who we are, what our view of curriculum and instruction may be, and what our view of knowledge and learning may be.

Based on this view the importance of various stakeholders that deal with the textbooks designing and use them is also highlighted. Theoretically speaking, policy makers, ministry of education, school boards, parents, students, researchers, publishers and authors have to be part of the textbook designing process. However, the constraints of the real world may hamper this process in many cases. In order to enhance the acceptance among the large demographics of textbook users, many publishers are selective about the contents. According to Venezky (1992:440) ‘publishers tend to avoid controversial content.’ This is one way of promoting the acceptance among the diverse users of the textbooks.

The paradigms of science education continue to influence the strategies of classroom practices and textbook designing to a certain extent (White 2001; Hartman and Glasgow 2002). The question for the textbook publishers and the practitioners is how far the current research is communicated to the related professionals (Figure 2). From the applied perspective, time constraints do not always allow for reviews of past research studies by educators and textbook authors. As a result, the process of integrating textbook research into textbook writing is hampered. Hartman and Glasgow (2002) have compiled a book called *Tips for the Science Teacher: Research-based strategies to help students learn.* This book has summaries of a large collection of research journal findings, with a guiding note for science educators. The need for a constant update is obviously a demanding task. Hartman and Glasgow (2002) have, to some degree, provided multidimensional frameworks to facilitate the writing of science textbooks to incorporate current research. Within each research paradigm and choice of addressing multiple intelligences, the level of priorities can shape many patterns of textbooks.

Figure 2: Communication between the three domains



1.3. Statement of the problem

The analysis of textbooks is crucial to analyze the effectiveness of a very common learning tool in our classrooms. According to Mikk (2000:15), "teachers rely on textbooks when structuring about 90% of lesson time." Many teachers who teach science in elementary level classrooms may not have specialized training to teach that subject, and in that case, textbooks become a guide for tracking the lesson plans. Mikk (2000:15) concludes, "pupils are working with textbooks for about 60% of the lesson time in some advanced countries." The children's level of interpretation of the same text could be very different from the expectation of the authors (Tamir 2000; White 2001). The variables and challenges attached to the designing of textbooks constantly influence the contents and the presentation of science contents in the elementary level textbooks. According to Sutton (1989:158):

> Some current books for school science are in danger of losing their clarity as texts in a welter of glossy illustration and other material such as cartoon strips (some excellent, some trivial). What exactly are these books: part worksheet, part inspiration, part wallpaper, trying to cater for several ability levels, but not really meeting any one level in a sustained way?

The above mentioned quote gives a glimpse of the challenges faced by our current textbooks. These types of conceptual, pedagogical, and curriculum theory gaps are also elaborated by Chambliss and Calfee (1998:6-7): "while today's instructional materials have much to recommend them, some of the strengths also lead to problems, and criticisms are legion. The debate sometimes centers around beliefs and values, a natural part of the democratic enterprise. But some of the very features with greatest appeal also spark the loudest protests." The notion of how well concepts and ideas are conveyed to enrich the critical thinking skills of students, as well as the role of the nature of science and the framework to foster constructive thinking, is a multilevel and multidisciplinary enterprise. Chambliss and Calfee (1998:6) explain: "for instance, the books are noteworthy for their attractiveness. The pictures, charts, and boxes are captivating, but often unrelated to the text. They can be seductive distractors, peaking interest rather than instructing, decorative more than substantive." The designing of textbooks has to deal with the size and the vocabulary level, especially in the science subjects. Chambliss and Calfee (1998:7) have explained that this problem "especially in science and social studies, arises from the emphasis on comprehension coverage. Science textbooks in grades 6-9 contain four to five thousand specialized or technical words, at least half of them new or unfamiliar." (ibid.:7). The classroom time provided to cover the science curriculum in Ontario is also very limited and sometimes teachers have to integrate certain aspects of the curriculum. The science vocabulary comprehension can be reduced in such classrooms if the textbook and other didactic factors are not designed to sustain in those learning environments. The question of augmenting learning from other textbooks along with one textbook also becomes an important issue to consider the science teaching programs. In the case of Ontario, how well teachers are prepared to teach science subjects when they are not specialized in science, raises the importance of science textbook research studies, since many teachers and students use the textbook as a main focus for meeting the science curriculum expectations.

The problem of textbook analysis is relatively complex in the Canadian education environment, where provincial curriculum designs vary and there are few studies conducted on Canadian textbooks (this can be confirmed by reliable internet search engines such as ERIC). This discussion highlights the importance and need for conducting research studies on Canadian science textbooks from micro-level, document analysis and other dimensions of pedagogy, knowledge transformation modes, science education, and related disciplines. The science textbooks also play an important role as a learning tool in Pakistan (cf. Mahmood 2011). On the other hand studies and articles highlight the problems in the science textbooks of Pakistan and emphasize to improve the science textbooks of Pakistan (cf. Mahmood 2011, Mohammad and Kumari 2007; Hoodbhoy 2012). The education system of a country also plays an important role in how textbooks are designed and used in the classrooms. In a study published from Pakistan on textbook analysis Mahmood (2006) informs:

> Most textbooks material suffers from a lack of coherence and focus. While publishers of the approved textbooks in Pakistan are eager to claim that their books are; (a) focused in terms of scope and objectives given in the National Curriculum and (b) aligned with educational requirements at the level for which they have been approved (Interview with officials of Punjab and Sindh Textbook Boards, July 20, 2004). In order to understand these claims, there is a need to analyze the textbooks development and approval processes, and approved textbooks themselves. (p.2)

In another important study published on this issue Mohammad and Kumari (2007) remark:

> "Our analysis of data identifies textbook related issues in terms of two categories: 1. Limited access to the information given in the textbook, i.e., issues related to its clarity and relevance for the students and teachers; 2. Teachers' limited use and appreciation of the textbook content, i.e., of the information as well as learning aids (pictures and activities) provided in the textbook. 'Access' in our paper has been defined in terms of the various gaps in the textbook content that restricted teachers' and learners' access to the information. Issues related to 'use' refer to teachers' inability to utilize the textbook effectively, resulting in failure to teach the scientific concepts in an effective way."

The above mentioned study clearly points a gap in our current research on this topic. It also brings to attention a need for finding ways to analyze science textbook of Pakistan and indicates need for finding ways to improve this process. The current study will have potential to analyze some aspects of science textbook contents and provide some arguments for making improvements. Some examples of successful practices will also be given for making pedagogical improvements. In the recent article mentioned, the use of word "limited" raises question on which textbooks have unlimited access. There will always be some limits on what is presented in the textbooks. Even the textbooks being published in the industrialized countries do not have "unlimited" access and their content is also being constantly studied for making improvements with the changes in policies, theory, research and practices.

The ERIC data also shows no study conducted in the past on the elementary level science textbooks of Pakistan which applied document analysis and student feedback to explore explanatory understanding indicators. Those arguments indicate there is need to analyze elementary level science textbooks from Canada and Pakistan.

A textbook study can provide some insight in investigating the challenges of the learning environment. The methods for textbook analysis are not consistent and the multidimensional contents and their manifestations used to design the textbooks have to be analyzed from multi-dimensions. According to Venezky (1992:457) "for the study of textbooks, exact methods are lacking". While referring to the reliability of the textbook analysis method, Venezky believes: "it is important that valid and reliable methods be used in their analysis, especially if both the manifest and the latent curricula are to be aligned with the needed curriculum" (ibid.:457). For this reason, the important task of textbook analysis demands the application of multilevel research study methods (cf. Chambliss et al. 1998; Lee 2007).

1.4. Purpose of the study

Graesser, Leon and Otero (2002:4) remark "promoting science education fits a prominent mission in virtually all countries and cultures. Science textbooks have obviously played an important role in this endeavour." One of the important aspects of the science textbook is to impart the concepts, despite learning variables. Purves (1993:17) point of view elaborates on comparing textbooks from the perspective of various readers who might have a variety of understanding of science concepts, based on their previous knowledge. Conversely, Peacock and Weedon (2002:196) argue:

> In science learning, it is ultimately the concepts that are important, and many concepts are difficult or abstract such as those concerned with forces, energy, three-dimensional motion, electricity and processes taking place sequentially over time, such as reproduction, evaporation and photosynthesis.

The understanding of science concepts is based on many factors, such as explanatory sentences, graphic communication, real-life experience connections, cognitive styles (DeBoer 1991), and readers' previous knowledge. As discussed previously, the importance of the textbook as a learning tool is obvious. There is a growing need to analyze textbooks to collect data for comparing the effectiveness, and probe ways to constantly upgrade the next generation of textbooks (cf. Newton et al. 2002; Collette and Chiappetta 1989).

The Ontario science curriculum provides many expectations to teach the concept of electricity to grade six students. One of the commonly used textbook for this topic *is Electricity—Science & Technology* published by Addison Wesley (1999). In the past, there is no study conducted on this textbook from the micro level and document analysis perspective. The research question is to explore the concern of the given textbook for the explanatory understanding. The current study analyzes some aspects of the textbook through the responses of students and the analysis of the text document by sentence categorization, paragraph analysis, and lexical-conceptual profile.

The Council of Ministers of Canada has placed emphasis on the effort to "reduce the volume of material traditionally covered in science curricula, and to ensure that students are not learning isolated bits of information, but rather developing a greater understanding of science." (Council of Ministers 1997:259). After this direction was given by the council, there were some changes made in the curricula and consequently in the textbooks published around that time. An analysis of the textbook(s) published (after those changes were recommended) can provide a critical review of the effectiveness of changes incorporated. The Government of Ontario provided science curriculum expectations that were published in 1998. A specific study that can thoroughly compare the curriculum modification aspects is beyond the scope of this study. The purpose of this study highlights the indicators of explanatory aspects in the relevant science textbooks CT and PT. and also compares the feedback of students on the use of this textbook along with other specific resources, relates the discussions on data to a variety of multidimensional studies, and discusses the implications for future science textbook designing.

1.5. Significance of the study

The ERIC data search shows that very few studies were conducted in Canada on elementary-level textbooks. Most of the previous studies were conducted in Europe and United States. Canadian researchers Roth et al. have recently published a book *Critical Graphicacy*. Roth et al. (2005) remarks on the cover of this book:

> School science is dominated by textbook-oriented approaches to teaching and learning. Some surveys reveal that students have to read, depending on academic level, between ten and thirty-six pages per week from their textbook. One therefore has to ask to what degree textbooks introduce students to the literary practices of their domain. Few studies have addressed the quality of science curriculum materials, particularly textbooks, from a critical perspective.

Overall, many studies conducted on the textbooks normally apply one type of analysis method. The current study is based on an empirical analysis on two groups of students and document analysis of the textbook. In this way the current study has a combination of linguistic and education related research issue. This study provides data to compare some aspects of how textbook approach can influence the responses of students. The study also provides a critical discussion on the presentation of information and shows some possible examples that can cause ambiguity to grade six level students. The future implications can be useful for textbook designing and classroom application.

The importance of textbook analysis has a wider scope than classroom-specific dimensions. Textbook research analysis and update has implications for improving learning in all parts of the world. As Farrell (2003:2554) found that "recent research in developing nations indicates that the single most important investment poor nations can make for improving the learning of their children is increasing textbook availability and quality". This need can also be addressed by conducting and sharing cross-cultural and multidimensional research studies on textbook analysis and curriculum designing. The current study also includes an elementary level science textbook from Pakistan, so that some research data can compare the indicators of explanatory understanding from that part of the world. This aspect also distinguishes the study with data collected from the textbooks of Pakistan along with other dimensions of the research frameworks.

The multidisciplinary nature of science education, textbook designing and education policy issues comprises a large spectrum of knowledge presentation and knowledge understanding models. Many authors assert this notion of learning as a combination of multiple elements: a challenge for textbook designing, textbook analysis, science concept attainment, and curriculum designing (cf. Johnsen 1993; Chambliss and Calfee 1998; Rowell and Ebbers 2004; McComas 2008; Koulaidis and Tsatsaroni 1996). The current study has collected data on a few specific dimensions using some unique combinations such as linguistics and education in terms of lexeme collection, document analysis, and student responses. The occurrence of lexemes is compared from a micro-level and document analysis dimension. The collection of data on lexeme occurrence, based on the textbook and student writing samples, is discussed from didactics, linguistic, and curriculum designing dimensions. The collection of qualitative and quantitative data is an attempt to make data more comparable from both dimensions of education research. Statistical comparisons are also supported with the qualitative factors to make this study extended for future research works. Some of the explanatory indicators given in the textbook are critically compared with a few aspects of concept formation issues, education policy structures, curriculum expectations and current theories of science education. The direct results of this study relate to the importance of using explanatory understanding modes of communication along with a range of didactic factors.

Chapter 2 LITERATURE REVIEW

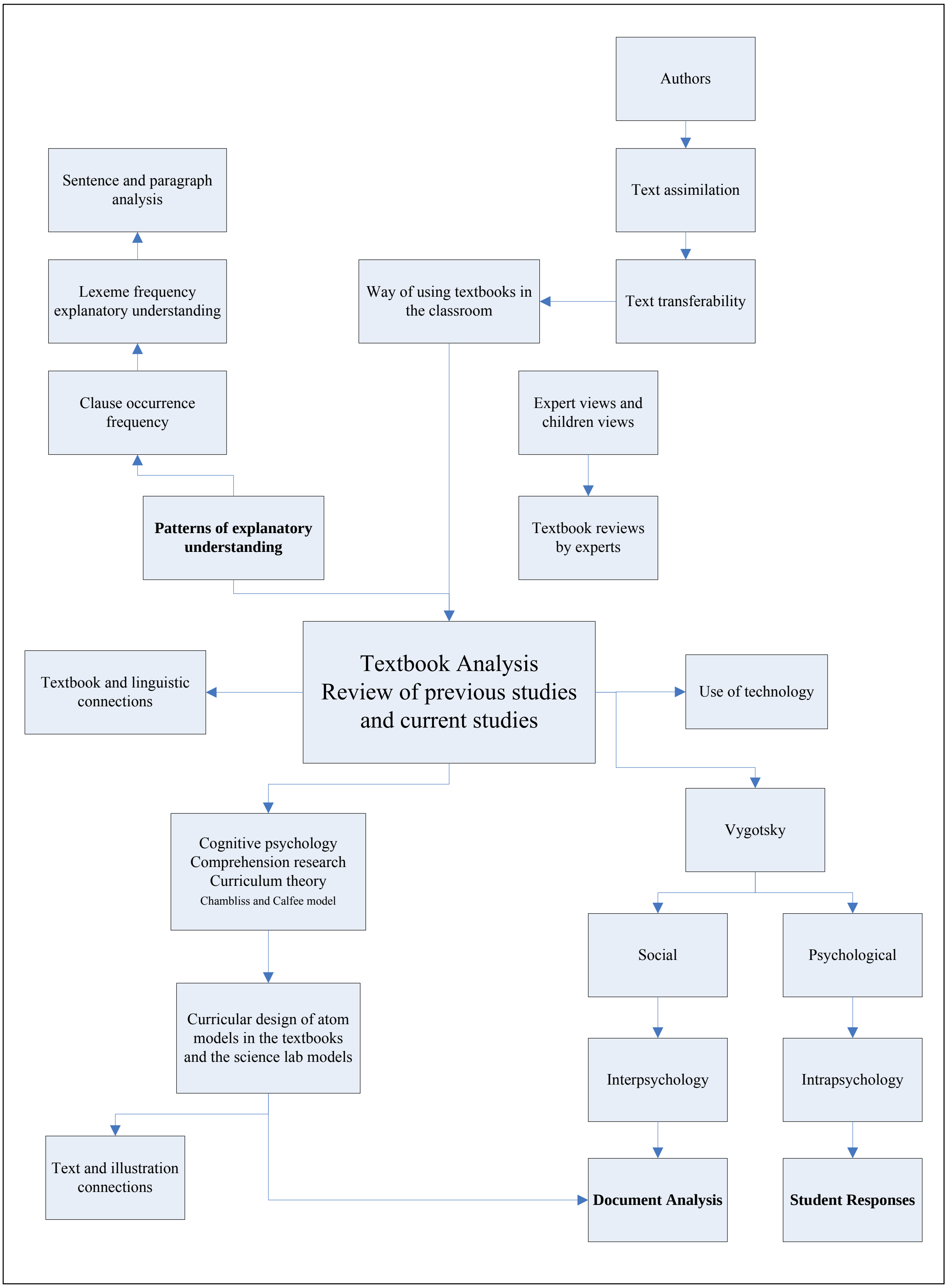
The organization of this chapter includes literature references and analyses which encompasses a range of studies conducted on this topic. Elementary science textbooks are designed in relation to multiple components; therefore this literature review includes perspectives of various related fields. The chapter includes studies on multi-level learners, influence of educational policies, science in relation to other curriculum domains, technology development and the current textbooks, contents and pedagogy research. This literature review also discusses and critically analyzes some textbook analysis methods used in the previous studies within the given parameters of those studies, which includes, refutation text analysis, scoring procedures, analysis report by experts, text and language connections, children responses, explanatory understanding indicators in the science textbooks. Although the theme of illustration analysis is not the focus of this study, since it has close links with textbooks and students' responses, therefore, some aspects of research and critical analysis of the role of graphics is part of this review. The topic of electricity in the science textbooks has close link with how the idea of atoms is presented in the textbooks. Previous studies on this topic are discussed and overall it contributes to making links between science textbook designing factors and the presentation of model of atom for explanatory understanding. This review shows need to conduct a research study on this topic and show importance for future studies. A Table is also designed to show some dimensions of research in this field. The Figure 3 shows the multiple aspects of textbook analysis and a review of previous studies with highlighting emerging pathways for the current study.

2.1. Multiple components of textbook designing

The designing of textbooks involves much proficiency from various domains. From language use to concept formation techniques, and from publishing standards to the demands of users, a vast range of disciplines have to work together towards the completion of a textbook. The multiple domain interaction in textbook designing gives textbook analyzers a reason to use multiple approaches. Despite conducting research from the perspectives of language, pedagogy, graphics, curriculum and cognitive explanation, new challenges are ever emerging—especially in the age of information. According to Venezky (1992:438):

> Since textbooks occupy one of the intersection points of education, commerce, and culture, no single framework can adequately encompass the different interpretive structures, research methodologies, and even language sets that exist for the study of this object. Instead, multiple frameworks are needed, with cross connections specified.

Figure 3: Textbook analysis, a review of previous studies and the current studies

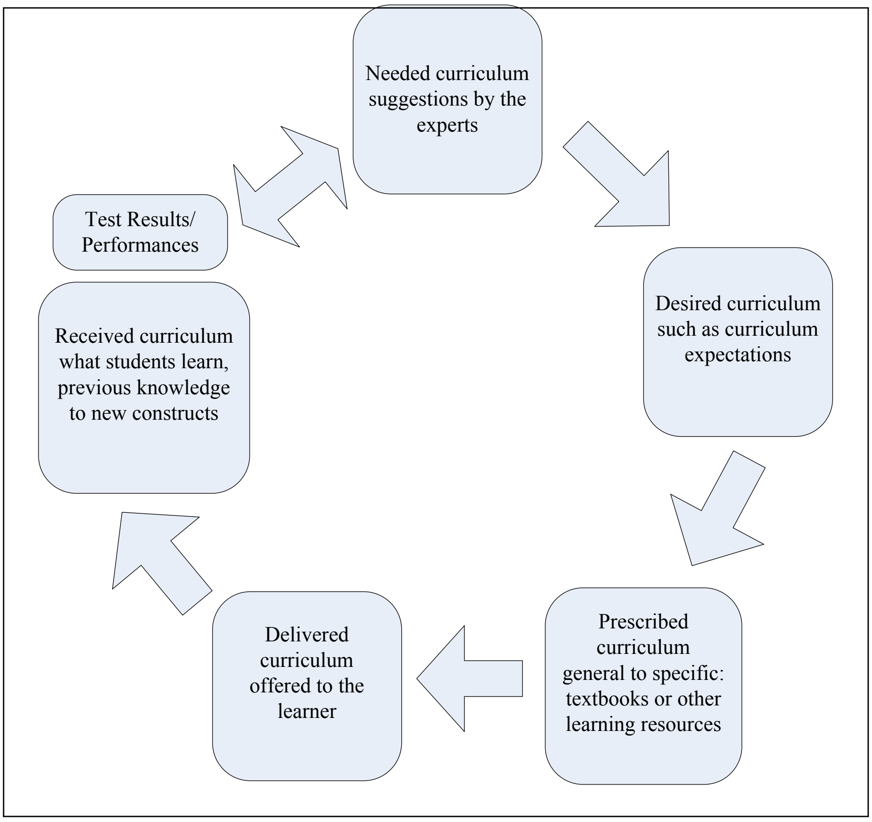


As a result of various political, social and academic movements, textbooks also come under criticism and analysis (cf. Hoodbhoy 2012; Giordano 2003; Chambliss and Calfee 1998; Vnenzky 1992; Whipple 1931; Cronbach 1955; Elliott and Woodward 1990). The curriculum is a complex chain in which textbooks are one aspect of the big chain. Venezky (1992) has elaborated curriculum chain as follows: Needed Curriculum, Desired Curriculum, Prescribed Curriculum, Delivered and Received Curricula (Figure 4). The education system(s) may have their own local preference in terms of fitting textbook at a certain level in the complex chain of curriculum connections. How text is compared to learning is also a focus of various domains. Armbruster and Anderson (1989:381) conclude:

> One factor affecting learning from text is structure. Structure refers to the way ideas are connected together in logical organizational patterns. A few basic rhetorical structures appear to reflect fundamental patterns of human thought: (a) simple listing – a listing of items or ideas where the order of presentation of the item is not significant; (b) conclusion/evidence—a special case of simple listing, consisting of a proposition and a list of reasons serving as evidence for that fact; (c) comparison/contrast—a description of similarities and differences between two or more things; (d) temporal sequence—a sequential relationship between items or events considered in terms of the passage of time; (e) cause—effect–an interaction between at least two ideas or events, one considered a cause or reason and the other an effect or result; and (f) problem— solution— similar to the cause—effect pattern in the two factors interact, one citing a problem and the other a solution to the problem. These basic structures can be subsumed in higher order structures that underlie particular text genres.

The importance of illustrations in the textbooks is a topic that has gained extensive research interest in the recent years (cf. Lee. 2010). Science learning has strong connections with images and illustrations. According to Lemke (1998) ‘‘Science is not done, is not communicated, through verbal language alone. It cannot be.’’ Lemke (1998) further emphasized ‘‘combine, interconnect, and integrate verbal text with mathematical expressions, quantitative graphs, information tables, abstract diagrams, maps, drawings, photographs, and a host of unique specialized visual genres seen nowhere else’’ (p. 89). Stern, Aprea, and Ebner (2003, p. 192) suggested about science ‘‘graphs and diagrams can bridge the gap between everyday knowledge based on verbal description, and mathematical formulas describing the central laws’’. According to Lee (2010) “Textbooks are among the most graphically populated print materials used for the communication and sharing of scientific ideas. Some researchers have found that nearly half of the page space in a textbook is dedicated to illustration (Mayer, Steinhoff, Bower, & Mars, 1993), and that up to 85% of those illustrations in a given science textbook lack a clear articulation of content relevance (Mayer, 1993)” (pg. 1100). Lee (2010) also elaborated that: “More concentrated analysis by Roth, Bowen, and McGinn (1999) reveals the majority of representations in biology textbooks tend to be iconic pictures and images (ones that directly resemble the objects being depicted) rather than more abstract or data-centered ones that professional scientists use (e.g., graphs, data plots). Roth et al. note also that on the relatively few occasions when more abstract or data-centered representations were used, they took the form of Cartesian graphs that depicted idealized and simplified patterns far removed from their professional analogs." Overall, the research studies have viewed the crucial importance of images and illustrations in the science textbooks, while the effectiveness of their designs and applications is still a vast topic to view them from the perspective of theory, research and practice.

Figure 4: The curriculum chain



The curriculum and textbooks also need to distinguish and emphasize on the notions of argument and explanation. In some recent literature this concept has emerged in ambiguous forms (Osborne et al. 2011). According to Osborne et al. (2011:634) an argument and explanation is distinguished as "an argument is a statement where the premises are stated as a means of proving or justifying a conclusion", "an explanation, what is to be explained is not in doubt and we reason from a *tentative premise* to a definitive conclusion." This recent research gives a range of ideas to re-view our curriculum outlines and textbooks with the clear understanding of arguments and explanation. The purpose of science education is to prepare students to apply higher level thinking and it requires explanation and argument clearly forming the foundation for elementary level science (Osborne et al. 2011). As our current literature gives strong emphasis on developing higher level thinking (cf. Braaten et al. 2011; Osborne et al. 2011), the gradual development of students skills in those areas have an important notion; higher level thinking also needs some foundation ground to build further.

2.1.1. The challenges faced by the textbook authors

The complexities of textbook patterns and concept connections make the job of writers extremely challenging. Writers have to consider the structure of the problems because the way information is presented has a close link with the learning of readers (Robertson and Kahney 1996; Rosenblatt 2011). The writer may not clearly know the cognitive styles, differential psychology, and social interests of their learners. The crucial place of the textbook in the big picture of the overall learning environment is a complex challenge for the textbook writers and publishers. The question of designing an effective textbook that will address the needs for all readers is not easy to answer. In many cases, publishers provide specific information to the textbook writers about the students' age and curriculum needs and other pedagogical factors. However, knowing all factors in the learning process remains an unknown entity for textbook authors. The challenge of textbook use in a learning environment has questions of assimilation and integration regarding the multiple intelligences of a student, as well as their present knowledge.

Even if writers can target successfully a specific readership, they are still left with the problem of how to present the material in such a way that it will be easily assimilated and readily transferred. Assimilation means the ability to integrate new material within existing knowledge. Transfer refers to the ability of a person to adopt a procedure learned in one context in order to use it in another (ibid.:96).

2.1.2. Textbook use and meeting the new challenges

Various authors also raise the fundamental question about the use of science textbooks, especially in the age of information and technology. The following comparison shows the position of some authors about this basic question. Among those who see the textbook as an important tool in the future of education are Sutton (1989) and Johnsen (1993). Sutton (1989:154) asserts "there will always be a place for textbook in science education." Johnsen (1993:327) thinks "textbooks have been and continue to be the most widely-used teaching aid." The other position is text might be challenged with the other new ways of learning. Wellingtion (2001:80) concludes "text will survive, even if textbooks do not." Some authors view the constant upgrading of the textbook as a tool to address the growing needs. Chambliss and Clafee (1998:13) stress:

> Each day brings new breakthroughs, and tomorrow's students need to be prepared for change and challenge. At the same time, the student population is becoming more diverse. Can books really compare any more? We think so.

The textbook industry also faces supply and demand trends. Perhaps therefore, only those textbooks will hold better position in the learning environment that will keep abreast with the changing trends and learning demands of the systems. The Chambliss and Clafee view has optimistic position for the future of textbooks with an emphasis on ongoing improvements for nurturing children's minds. The growth in quality textbook publications that meets current demands can happen with vigorous effort in textbook research analysis.

According to DiGiuseppe (2007:15) "some researchers have found that some teachers (the less able) often rely on textbooks for support, while other (more able) teachers rely on textbooks for convenience." How teachers use textbooks is a different perspective of research study that can be addressed by some other type of analysis.

2.2. Studies on textbook design and related factors

A range of studies have been conducted in the last three decades about the analysis of textbooks. As there is no litmus test for analyzing textbooks, researchers have therefore used a combination of various comparison techniques (cf. Johnsen 1993; Chambliss and Calfee 1998; Wellington 2001, Cohen and Steinberg 1983; Newton, Newton, Blake, and Brown 2002). The focus of this study is on grade six students (learning about electricity using a textbook) in a multicultural, inner-city school. In relation to those parameters, some common forms of textbook studies are: micro-level (testing students' comprehension/learning from a textbook reading), review or analysis of a textbook by experts of a given field, study of the teacher's role in using and understanding the textbook concepts, readability test, analysis of text design, and comparing balance of 'nature of science.'

2.2.1. Textbook designs from theoretical bases to the applied form

Well-designed science textbooks facilitate the students' understanding (Hoodbhoy 2012; Chambliss and Calfee 1989). The flipside is that poorly designed textbooks can lead to misconceptions (Marshall 1986; Chambliss and Calfee 1998; Hubisz 2001; Newton, Newton, Blake, and Brown 2002). As there are many factors involved in the designing of an effective textbook, what makes textbooks well-designed remains a topic of debate and further research. Chambliss and Calfee (1989) have presented an approach for textbook designing that is based on the following three dimensions:

- Cognitive psychology
- Comprehension research
- Curriculum theory

The textbook designing has to focus on concept formation effectiveness, addressing various learning styles according to the content and addressing curriculum guidelines to make it effective for the required readers. A coherent design has three sections as Chambliss and Calfee (1989:308) conclude:

> We contend that a coherent design is composed of three critical ingredients: a set of distinctive elements, *linkages* that bind the elements, and a *theme* that gives overall meaning and shape to the creation.

The design of textbooks is also distinguished by two factors: descriptions and sequences. According to Chambliss and Calfee (1989) four *descriptive patterns* are: list, topical net, hierarchy, and matrix; and three *sequential patterns* are: linear, causal chain and branching tree. The nature of the topic and the level of the readers also play a role to vary the patterns of writing textbooks.

The patterns also work as a template and a structure to develop the complete pattern of a textbook. Consider a textbook written about electricity in the topical net format that shows topics as: clouds, cells, fan, and computers. Although all topics are related to electricity, the topical net format can leave the actual concept of electricity not very well explained according to the needs of students. In many cases, causal narrative can be a better choice for describing the taxonomies of an idea that is best explained by linear development. Ideally, textbook writing attempts to combine the demands of schools, researchers, teachers, and children. It is not easy to meet all those expectations in one single book. According to Chambliss and Calfee (1998:41):

> Textbook publishers experience strong market pressures to produce writing that does not match many of the principles of good writing taught in composition courses and verified by educational research.

Talking about the comprehension, studies show three factors play an important role in this process: structure patterns, coherence and text contents, and the level of readers (Garner 1987, 1992; Chambliss and Calfee 1989; Chambliss and Calfee 1998). The text can facilitate understanding through the use of early organizational signals, structural summaries, coherence, tighter linkages. When the readers' mind decodes the words and concludes meaning, the role of previous knowledge is also inevitable. One of the basic principles of constructivism reveals 'knowledge is not transmitted but actively constructed by the learner.' (Diakidoy; Kendeou; Ioannides 2003:336). Some textbooks provide various activities (such as thinking, comparing, and experimenting) to encourage a constructive learning model. On the other hand, the textbook writers are left with the choice of applying various modes of explanation to connect with the range of readers. The levels of learners also vary in terms of redefining the text in their own minds and make meaningful connections with the text. The interdisciplinary foundation of those components is linked with some paradigms of various disciplines such as psychology, linguistics, pedagogy and philosophy (cf. Venezky 1992; Chambliss and Calfee 1998; Johnsen 1993).

2.2.2. The textbook analysis methods

As discussed earlier, the designing of textbooks has many factors and challenges to grapple. When it comes to evaluating or analyzing textbooks, the challenges of textbook designing and research analysis methodologies are combined. Can we evaluate the effectiveness of textbooks by one single method? In their analysis on this question Chambliss and Calfee (1998:115) say:

> Evaluating the design of textbooks has proven to be a knotty problem. It has been by no means obvious how to recognize curricular, comprehensibility, and instructional themes in a passage of several hundred words; few have tried to analyze books of several hundred pages. State, district, and classroom textbook selectors have used readability formulas and checklists to evaluate, compare, and choose textbook series. Publishers have often designed their books to meet readability and checklist criteria. Readability formulas and checklists each have strengths and drawbacks.

Some of the drawbacks of readability formulas include, obtaining different results on the same passages, ignoring writing structure analysis, and less emphasis on conceptual details. Textbooks written with this pattern demand two things of the readers (children): to understand the sentence connections and to extract conceptual details (cf. Chambliss and Calfee 1998). The difficulty of word level has also links with linguistics and education. The challenges of language comprehension for children are combined with the highly abstract concepts of science. Despite this challenge the argument to include scientific terms in the science textbooks has some merits, which leads to the question how to integrate science terms in a simpler way of understanding. Cohen and Steinberg (1983:100) conclude:

> Students who receive technical vocabulary instruction prior to reading such prose would be expected to show improved comprehension. Because technical terms are an integral part of science prose, their numbers should not be reduced by publishers in an attempt to improve readability.

This position is also translated in the curriculum designs. The *Ontario Science Curriculum* (1998) emphasizes the use of science related terms as shown in the following curriculum expectation:

> Use appropriate vocabulary, including correct science and technology terminology, in describing their investigations and observations (e.g., use terms such as *current*, *battery*, *circuit*, *conductor*, *insulator*; *positive* (plus) and *negative* (minus) *charges* for electrically charged materials; *north pole* and *south pole* for magnetic materials)" Ontario Science Curriculum (1998:65).

A more useful combination of the two approaches comes by providing the concept with easier language, allowing the student to make inferences of the word and its science collocations with gradual interaction. This process can reduce the possibility of conceptual ambiguity due to unfamiliar words. Another related issue, but not the main research question of this study, is the multiple meaning of the same word in various domains (for example the word ‘work’ has a different meaning in daily language as compare to science). The multiple uses of words in science textbooks and other subjects is in itself a field of research, however it is not the main topic of this study.

2.2.3. Textbooks and linguistic connections

Linguistics is closely connected with the designing and some forms of the analysis of textbooks. Language is one of the major components of conveying concepts in the textbook (Wellington 2001). The use of language varies in the realm of scientists and the writers of textbooks for children. Scientists tend to use highly sophisticated language for conveying a scientific idea to fellow scientists, while writers of children’s books target easy to understand language in the textbook. How well can both domains work together to communicate the ideas in the most effective way? According to Gould (2003:132):

> Because we have cut ourselves off from scholars in the humanities who pay closer attention to the modes of communication, we have spun our own self-referential wheels and developed artificial standards and rules of writing that virtually guarantee the unreadability of scientific articles outside the clubhouse.

Gould has questioned as to why scientific text has to be so unreadable. If the language is simplified in the science books/articles, does this mean that a large population can have some understanding of scientific ideas? The challenge faced by the educators is also concluded by Chambliss and Calfee (1989:311): “the challenge of education is to move students from their naive understanding toward the framework of the expert.” This process involves classroom composition, teaching factors, resources, and the overall learning environment. In this big picture, although the textbook is one factor, attempts have been made to collaborate many pedagogical and administrative factors (Apple and Christian-Smith, 1991; Johnsen 1993).

2.2.4. Some implications of educational linguistics in science education

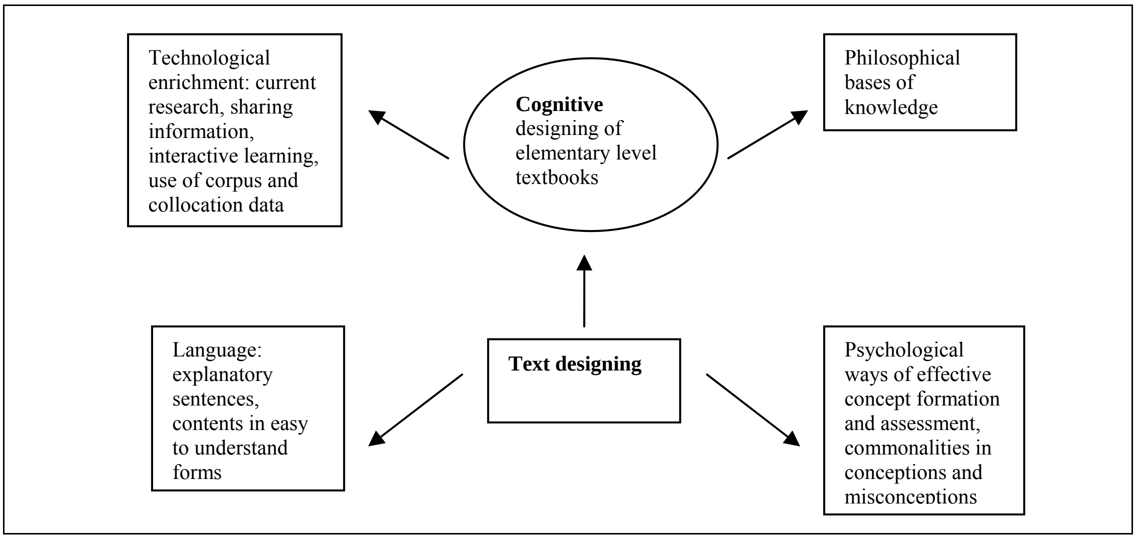
For many linguists, it is the realm of applied linguistics which deals with education related issues. Due to the vast parameters of applied linguistics, this notion could be correct (Hult 2008). The question is how educational linguistics is distinguished from applied linguistics and what its implications are for science education at the elementary level. The answer goes beyond the scope of the current study. A brief account is given below, due to the close links between the related fields. Hult (2008:10) remarks:

> As an area of inquiry, educational linguistics is young. Its naissance occurred in the early 1970s with the work of Bernard Spolsky. The history of educational linguistics in inextricably linked to applied linguistics, with which it continues to have a symbolic relationship. At the same time, educational linguistics has developed a unique niche in its directed focus on language and education.

Applied linguistics is commonly understood as a multidisciplinary approach. In interdisciplinary and multidisciplinary approaches, the researcher begins with the knowledge of some set of disciplines, and then probes interrelated connections. In the transdisciplinary research process, the inquirer starts with a theme and then applies relevant methods to probe the problem. In a recently published book, Hult (2008: 13) argues: "Applied linguistics has had a broad scope since its inception, but it is language and education that has come to be dominant." The more focused view of language and education is explained by the problem-oriented approach of educational linguistics (Hornberger 2001:9). Hult (2008:18) explains that "educational linguists are concerned with the dynamic ways in which theory, research, policy, and practice inter-relate. All work done under the rubric of educational linguistics, then, is focused on relationships not on theory, research, policy, or practice in isolation."

Hult (2008:21) also claims that "with its roots in the controversies of applied linguistics, educational linguistics has grown into a thriving field of inquiry focused on language and education. Its transdisciplinary nature has allowed it to flourish in a wide range of disciplinary climates." Gould (2003) has elaborated on the debate on the interdisciplinary links between science and language scholars. The artificial standards of science-related ways of communication and general language tend to raise barriers between the disciplines (cf. Gould 2003:132). The use of science terms, despite being the same in everyday vocal and writing modes, may differ significantly when considered in the realm of science meanings. A remarkable example for the topic related to electricity is the use of the words energy, force and power in science related context and the everyday use of those terms. The question even for frontline teachers is how to distinguish between them, as to provide a clear distinction if those words have the same meaning or if they have a precise difference with reference to science. Perhaps it is due to this reason that the role of icons, inscriptions, and analogies becomes one of the communication facilitators between science concepts and linguistic modes (cf. Roth et al. 2005; Chiu and Lin 2005). The textbook authors and curriculum policy designers have to consider the growing impact of how educational linguistics can be transformed with the field of science education. Within the framework of educational linguistics and the field of science education perhaps more integrated modes of communication can be considered to develop a research continuum for interdisciplinary and transdisciplinary domains. A further vibrant collaboration of theory, research and practice can open doors for **science education linguistics**. The effective textbook development needs theory, research, policy and practice that can organize patterns for elements and link design (cf. Chambliss and Calfee 1998). A combination of these factors is important in cognitive designing of textbooks as language and other related factors such as philosophy, psychology, and technology are also considered as important components in the process (Figure 5).

Figure 5: Cognitive designing of elementary level textbooks



2.2.5. Effective role of curriculum factors

The parameters of the curriculum and the administrative challenges are embodied by many aspects of schooling and sociology that are beyond to the scope of this research. An important aspect of this process is the effective learning pattern of textbook design. Chambliss and Calfee (1998) give several patterns of good textbook design with effective themes, elements, and linkages in relation to comprehensibility, curriculum and instruction. Interesting text, familiar vocabulary, communicating expert opinion in a simplified way, and involving students to extend the application of ideas are some important characteristics of a well-designed textbook for children.

2.2.6. The new Ontario science curriculum expectations and the current challenges to teach the topic of electricity

A document was released by the Ontario Ministry of Education regarding the science curriculum expectations. The use of the relatively new document in the classroom will take some time before analysis reports will be published. The new Ontario Science and Technology Curriculum (2007:119-120) has the following expectations (Electricity) for grade six students that are pertinent to this research study.

"1. Relating Science and Technology to Society and the Environment
By the end of Grade 6, students will:
1.1 assess the short- and long-term environmental effects of the different ways in which electricity is generated in Canada (e.g., hydro, thermal, nuclear, wind, solar), including the effect of each method on natural resources and living things in the environment

Sample problems: (a) Electricity in Ontario is generated by nuclear plants, hydroelectric plants, coal-fired plants, and natural gas plants, and a small percentage is obtained through alternative energy sources. Choose an electricity-generating plant that supplies electricity in your community, and compare the environmental effects of the generating method it uses with a method used in another part of the province.

(b) The James Bay Hydroelectric Project was one of the biggest hydroelectric developments of the past century, but it has also had a serious impact on the environment and the James Bay Cree people. Investigate both sides of this issue, and suggest how things might be approached differently today.

1.2 assess opportunities for reducing electricity consumption at home or at school that could affect the use of non-renewable resources in a positive way or reduce the impact of electricity generation on the environment

Sample issue: Peak demand times for electricity are morning and early evening. Because electricity cannot be stored in a cost-effective way, it must be supplied as it is being used. This means that almost all of a utility's available power plants must run to meet the demand and prevent system outages. Some utility companies are considering a plan to pay consumers to reduce their electricity consumption, especially during peak hours. This plan would not only reduce demand but would also reduce the cost of electricity for all customers and the impact of electricity production on the environment.

2. Developing Investigation and Communication Skills

By the end of Grade 6, students will:

2.1 follow established safety procedures for working with electricity (e.g., ensure hands are completely dry when working with electricity; be aware of electrical hazards at home, at school, and in the community)

2.2 design and build series and parallel circuits, draw labelled diagrams identifying the components used in each, and describe the role of each component in the circuit

2.3 use scientific inquiry/experimentation skills to investigate the characteristics of static electricity

Sample guiding questions: Is static electricity really static? Explain. What causes static electricity? Is it easier to generate static electricity in a dry room or a humid room? Why? Which materials accept a charge better than others? Where would you find static electricity in action?

2.4 design, build, and test a device that produces electricity (e.g., a battery built from a lemon or potato; a wind turbine)

Sample guiding questions: How can you find the positive and negative ends of your battery? How much voltage does your battery produce? How can you increase the voltage? What would happen if you exchanged the lemon for an apple? For a potato or a carrot? For other fruits or vegetables? How does a wind turbine produce electricity? Is this a good method of producing electricity? Why? Why not?

2.5 use technological problem-solving skills to design, build, and test a device that transforms electrical energy into another form of energy in order to perform a function (e.g., a device that makes a sound, that moves, that lights up)

Sample guiding questions: What function will your device perform? What does your device transform the electrical energy into? How does your device work?
2.6 use appropriate science and technology vocabulary, including current, battery, circuit, transform, static, electrostatic, and energy, in oral and written communication
2.7 use a variety of forms (e.g., oral, written, graphic, multimedia) to communicate with different audiences and for a variety of purposes (e.g., using scientific and technological conventions, create a labelled diagram showing the component parts of the device they created to transform electrical energy into another form of energy and perform a function).
3. Understanding Basic Concepts
By the end of Grade 6, students will:
3.1 distinguish between current and static electricity
3.2 use the principles of static electricity to explain common electrostatic phenomena (e.g., the attraction of hairs to a comb that has been rubbed on a piece of wool; the attraction of small pieces of paper to a plastic ruler that has been rubbed with a rag; the attraction of pieces of clothing to each other when they come out of a clothes dryer)
3.3 identify materials that are good conductors of electricity (e.g., copper, gold, silver, aluminum, water [when it has a high mineral content]) and good insulators (e.g., glass, plastic, rubber, ceramics)
3.4 describe how various forms of energy can be transformed into electrical energy (e.g., batteries use chemical energy; hydroelectric plants use water power; nuclear generating stations use nuclear energy; wind turbines use wind power; solar panels use energy from the sun; wave power stations use energy from ocean waves)
3.5 identify ways in which electrical energy is transformed into other forms of energy (e.g., electrical energy is transformed into heat energy in a toaster, light and sound energy in a television, mechanical energy in a blender)
3.6 explain the functions of the components of a simple electrical circuit (e.g., a battery is the power source; a length of wire is the conductor that carries the electrical current to the load; a light bulb or motor is the load)
3.7 describe series circuits (components connected in a daisy chain) and parallel circuits (components connected side by side like the rungs of a ladder), and identify where each is used (e.g., some strings of patio lights are in series circuits – when one light burns out, the whole string goes out; parallel circuits are used for wiring lighting and electrical outlets in your house – when one light burns out, the others keep burning)
3.8 describe ways in which the use of electricity by society, including the amount of electrical energy used, has changed over time (e.g., drying clothes in a dryer instead of using a clothesline; playing video games instead of playing board games; using electric lights instead of candles)".

The Ontario science curriculum expectations for 2007 are augmented with some examples to elaborate the pedagogical parameters of grade six levels. This type of example use was in very limited form in the 1998 curriculum. A new textbook written on those lines has yet to be analyzed. The 1998 curriculum has an expectation "describe the relationship between electricity and magnetism in an electromagnetic device," while a clear expectation on the link of electricity and magnetism is not available in the 2007 curriculum expectations. In order to explain the phenomenon of electricity generation, the link of electricity and magnetism is very important (cf. Chiu and Lin 2005). The curriculum expectations for 2007 have a relatively detailed component on electricity and environment-related issues. The actual classroom delivery of the new curriculum expectations will provide opportunities to research and compare the effectiveness of the changes made. The new curriculum has not directly emphasized the electron or atom-related explanation of the word electricity. The delivered curriculum of every related class may explore this concept in a variety of ways. Future research studies might be able to analyze those aspects of theory and practice.

2.3. Science text comprehension dimensions

Science text is comprised of various components and the comprehension of text is also a multi-frame process. Tapiero and Otero (2002:179) explain this aspect as: "most models of text comprehension assume that readers create a multilevel representation of texts. These text representations in memory are coherent wholes in normal and successful reading." The spatial dimension between various conceptual indicators is important to create effective situation models using text and visuals (cf. Tapiero and Otero 2002). This notion has played a role in the designing of resources applied in the experimental groups, in which text and visuals facilitated conceptual clarity that was not included in the textbooks analyzed for this study. The scope of comparing science text comprehension has many dimensions and a range of studies have been conducted from various perspectives.

One dimension to compare the comprehension aspects is to explore student responses to a text which has contrasts of semantic directions. A study conducted by Diakidoy, Kendeou, and Ioannides (2003) shows the effect of using 'refutation text.' The study concludes students who used refutation text in addition to the regular text performed better than those who did not use it. Perhaps the contrastive comparison of ideas facilitates the constructive learning process. Textbooks have gained a specific pattern in mind, therefore publishers may not quickly move towards including refutation text in children's science textbooks.

2.3.1. Analysis of understanding patterns

While comparing the nature of explanation in science, Keil and Wilson (2000:281) remark: "We think that there is much overlap between the form of everyday explanation used by nonscientists and explanations used by scientists."

The critical analysis of an everyday experience based on common results and generalizing the principle that will follow same conceptual framework brings some notion of science in everyday life. The link between scientific explanations and everyday explanations can be integrated by the following: theoretical base for a phenomenon, expand the application to other situations, extend links to relate to a conceptual framework (cf. Keil and Wilson 2000). The conceptual link of everyday situations with the scientific phenomenon has a different learning level when it is compared by the philosophers of science and as it is linked in the science textbooks. How well do children's books show integration of those ideas? Children's textbooks cannot show many possible extensions and applications of the scientific ideas as other publishing factors (size, readability, target audience interests, marketing preferences etc.) can also take precedence over curriculum goals or specific individual learning needs (Johnsen 1993; Venezky 1992). The textbook authors target a wide range of learners using the same text, while common textbook analysis focuses on one specific group of students or a specific type of testing. This situation is not easy to streamline and requires flexible yet comprehensive efforts on the part of textbook authors and textbook researchers. Despite various challenges at pedagogical and economic levels of textbook designing, it is possible to give more explanation in the textbooks to describe the depth of scientific processes or the reasoning for a phenomenon according to the students' level. Nevertheless, how that process will impact student learning needs to be researched further. Simply not giving enough sentences (or clauses) to explain scientific concept can undermine the possibility of conveying the concept to children.

2.3.2. Exploring concerns for explanatory understanding in the textbooks

Newton et al. (2002) have analyzed textbooks by classifying clauses into the following groups: condition, consequence, causal explanation, purpose, prediction, aim, directed attention, irrelevant, and not differentiated. A schedule is designed to classify the clauses along with the order of priority to avoid overlap of clauses. The logical deduction is that, if the writer is more concerned with the "explanatory understanding" there will be more clauses in the category of 'consequence, purpose or explanation,' because they are commonly used to ask for reason or exploring in science. Out of many books analyzed on clause types, many books show a pattern of clauses that leads to hypothesize a lack of concern for the explanatory understanding. Newton et al. (2002) indicate the need to incorporate explanatory understanding in the science textbooks. The authors put emphasis on the occurrence of *clauses,* but also assert that "there is no direct or simple relationship between concern for explanatory understanding and the frequency of occurrence of such clauses" (ibid.:230).

Despite differentiating the clause types, the possibility of individual preference can translate into differential selection of clauses. If the results of this study are viewed together with the textbook design models of Chambliss and Calfee (1998) it shows crucial information to enhance explanatory understanding elements and linkages in the text designs.

2.3.3. Textbook presentation styles

From a historical perspective, the development of textbooks over a period of time shows some changes in the text structure and presentation of the material (Sutton 1989). Whether the concept formation has really improved with the modern techniques of textbook presentation or not, some apparent changes are seen from the physical dimension of textbooks (a constant change in size, color, graphics, and text format). Lynch and Strube (1985) conclude that textbooks have only slightly changed in the last century. The changes in pictures and page design are more of apparent physical nature (Sutton 1989). When a new textbook venture is started, will the authors realistically study previous research on textbooks? Perhaps more integrated efforts are needed to fill the gap between the authors of children's textbooks and the textbook researchers. Johnsen (1993:348) raises the following questions:

> Which system is used to communicate views and results within the textbook research community while the researchers themselves are busy collecting and processing material? Which teachers get the opportunity to contribute their experiences before the results are printed in a journal they may never read? Which pupils ever hear about it?

The crucial need to enhance communication among the textbook designers and users is a growing concern. The current technological tools can facilitate this communication process to some extent. For detailed pedagogical application, effective empirical testing with mixed-method analysis will be useful. Perhaps children's research journals that can convey research trends from the mainstream journals in simplified form can facilitate to bring the learners, textbook writers, and researchers together to some extent to enhance mutual communication. As a result, textbooks will reflect a strong communication link between the theory, research, and practice.

2.3.4. The use of textbooks in the classroom

Driscoll et al. (1994) have conducted research to see how textbooks are used by the grade eight students and teachers. Their results indicate textbooks were mainly used as a dictionary and this is perhaps due to accentuating learning vocabulary for performing better in the tests. While discussing the role of textbook and the publishers' perspective the authors say:

> Publishers typically prepare textbooks with an eye toward covering the traditional topics of the subject matter, while at the same time incorporating unique features that will outsell the competition. Few publishers view this as a process for creating *instructional* materials. Rather, they see it as creating *teaching* materials, leaving the accountability for teaching effectiveness to teachers. (ibid.: 80).

The variety of school settings and how a classroom program is run has a wide range of controlling factors. The urban population of a city has many other challenges attached to the classroom instruction. While a teacher tries to deal with a specialized subject, such as science, the time pressure to address many social, academic and administrative expectations within limited resources leaves teachers to use many modifications and extended homework assignments. In this situation, the textbook becomes a crucial learning aid inside and outside the classroom. While discussing the importance of textbooks Sutton (1989:154) argues:

> The problem seems to be how to get them into a useful relationship with other reading material that a teacher might need in order to engage the minds and feelings of learners, especially of learners who are not initially seeking to understand the grammar of a subject. I suspect that the most effective relationship would be divorce. Separate the textbook with all its implied certainty and deliberate avoidance of ambiguity, and have another kind of book that really does offer certainty for the learner to resolve.

In the real world, this approach has perhaps not been fully applied at the middle school level.

2.3.5. Use of technology and the new models of textbooks

Science learning is also broadening the scope of learners through the use of technology (cf. Perales and Vilchez 2002). According to Wellington (2001), science learning is about more than just the use of textbooks, as the Internet is also an important source of learning about science. Many students refrain from learning science at the high school level. Although many of those students will not be going to the laboratory, they will still be exposed to the text in science, therefore, there is still a need that the ‘pupil need to be taught to read in science.’ (ibid.:80). How to effectively facilitate the concept ‘read in science’ is a big question for educators. A more common way is to incorporate a combination of strategies for all learners. If text will survive, maybe the textbook will also be there in the future, but in varying formats. With the onset of computers, a whole new era of online books (multimedia) is also growing, as well as constantly changing shapes and formats (cf. Rowell and Ebbers 2004; Roscoe and Mrazek 2005). However, the question of authenticity and academic effectiveness remains a challenge along with the new authentic research analysis of those resources.

Marton (1986:31) explained phenomenographic research as “qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and phenomena in, the world around them….we try to describe an aspect of the world as it appears to the individual.”

Dall’ Alba et al. (1993:622) applied the phenomenographic approach to explore the “textbook treatments and students’ understanding of acceleration.” Dall’ Alba et al. (1993:622) assert:

> The present study does not focus on the acceleration of a falling object, nor is it solely concerned with features of the students themselves (as might be the case in some traditional psychological studies). Rather, the focus is relational in the sense that it is concerned with the relation between the students and the acceleration of the object, that is, with the way in which the acceleration of the object is understood or perceived by the students.

For the future studies, perhaps the parameters of this study (Dall’ Alba et al. 1993) can be extended to explore the phenomenographic links, in relation to the static charges and the students, to understand the concept of electricity. The results of that study may provide information on the possible extent of the use of the phenomenographic approach in textbook designing.

2.4. Textbook review by the experts

Some studies focus on the analysis of experts against their own reflection or check list. Hubisz (2001) reports on a study conducted to review the errors, accuracy, readability, attractiveness, pedagogic effectiveness and other factors. Nine reviewers critically analyzed 12 physical science textbooks designed for students in grades 6-8. This study appears to be based on the direct reflections of the reviewers. Hubisz (2001:306) remarks: ‘Not one of the books we reviewed reached a level that we could call ‘scientifically accurate’ as far as the physical science contained therein.’

2.4.1. The expert analysis and children responses

In terms of research methodology, some researchers would prefer an empirical study on children. However, if the scientific or linguistic accuracy is a concern in the textbook, a direct analysis of reviewers provides crucial information. It is very difficult for grade 6-8 level students to find mistakes on their own in the text. Some reviewers with expertise in science, linguistics and pedagogy can give an experts’ perspective on textbook analysis. That review indicates some shortcomings in content or style. Those results can be augmented with the use of other methods of analysis for more comprehensive results. There is clear shortage of research studies on textbooks that have applied multiple methods on the same textbook so that data can compare what students learn from the text and what design analysis shows.

Hayes and Flower (1980) are commonly quoted for suggesting the earliest model for “general cognitive theory of text production.” A distinct characteristic of the Hayes and Flower (1980) model is describing writing as a problem-solving activity. In order to apply a problem-solving strategy, the writer aims for a goal to produce the written work. What effect that writing will have on prospective readers? This question facilitates to envisage a pattern for the writing process. A backward model works as a guide in the writing process to achieve those goals in writing. Hayes and Flower have identified three cycles of this process: planning, translating, and revising. The planning stage includes identifying contents, structure and theme; the translating stage includes the process to realize the structure as complete text; and the revising stage includes polishing the writing to align writing goals with the produced text. According to Torrance (2006:679):

> Hayes and Flower provided hypotheses about how planning, translating, and revision processes might function, although the problem-solving framework in which these were couched has typically not been adopted in subsequent research. Many researchers have, however, used Hayes and Flower's terminology.

The responses of students' writing and their textbook comprehension skills and learning from other resources learning could be useful in improving textbook designing.

2.5. Comprehension analysis models

Walpole (1998) argues the use of teaching text along with other concept formation tools: assessing text knowledge, cooperative writing, and interactive discussion. Walpole also gives ideas to ask students to write a summary or conduct student interviews to assess text understanding. It is useful to get assessments prior to teaching, however, the availability of time, resources and other administrative factors may reduce options. Additionally, students' interests on various topics may also vary the results of assessments. Walpole (1998:358) concludes:

> Comprehension is not just finding, answering, or recognizing. Comprehension is building understanding, both of a particular text and of the more global concepts around which it is built. It is an active and demanding process, especially when children are reading to learn new and difficult concepts. It is time that we examine texts in the instructional context in which they are used so that teachers can craft comprehension instruction that builds bridges between the demands of the texts and the needs of their children.

The question is: how we will know the underlying learning processes are meeting the needs of all children? Also the comprehensive nature of comprehension perhaps gives a rationale to apply multiple strategies for textbook analysis to substantiate feedback from a variety of dimensions of text designing and learning. It is true that all analysis methods are not easy to apply in one research study, however, text design analysis (input) and students learning (output) from it gives more stability to research data. As Vygotsky (1997) has emphasized the two planes role in the cultural development of the children; between the people (interpsychological) and then within the child (intrapsychological). The social and psychological frames play a pivotal role in this process.

2.6. Studies on the use of curricular designs of atom models for instructional purpose

One of the focuses of the current study is to investigate the explanation of electricity as given in the textbook CT. The scientific nature of this concept is closely associated with the concept of atom and electron flow. A review of literature shows that there are very few studies conducted on the atom model in elementary level science textbooks, and there are only a small number of students learning from those models (cf. Justi and Gilbert 2000; Nersessian 1992). Due to the atom model's relevance to the textbook analysis and explanatory understanding of electron flow, some previous studies are discussed in this regard. Since the concept of electrons may appear relatively more abstract for grade six levels, students are more comfortable with the models of the atom that are easily visualized compared to more abstract forms (cf. Harrison and Treagust, 1996 and Justi and Gilbert 2000). Harrison and Treagust (1996) explored Grade 8-10 students' mental models of atoms and other parts of it. Based on the students' responses, this study shows that many students preferred models that are both discrete and concrete. Modeling can facilitate understanding but the pedagogical question is many Grade 8-10 level students find it a complex task to differentiate between models and reality. Harrison and Treagust (1996) studied student learning patterns by giving them the opportunity to draw an atomic model of their preference. In the next phase, students were shown six diagrams of atomic models that are commonly used for teaching in the classrooms. Students were encouraged to choose a diagram that represents their model in the most comparable way. The results indicated that 46% of students preferred the orbit model, 55% thought that atoms are spheres, and 32% drew simple diagrams with a nucleus and electrons.

Some distinct atomic diagrams used as curricular models are shown in the studies of Justi and Gilbert (2000) and Harrison and Treagust (1996), along with the student-made models. Student models included a nucleus in the centre and the orbits outside to show the electrons, as well as more modern models with electron clouds in which the whole atom looks like a spherical object. An important conclusion of Justi and Gilbert (2000:1006) discusses the links between the hybrid models and abstract models in teaching: "If students were mixing such different representations and reducing a very abstract model to a more simple and concrete one, this may be a result of the use of hybrid models in teaching." The current study has a link with this finding that the student-made models will be compared with various curricular models of atoms as shown by Justi and Gilbert (2000). The additional resources used for the experimental model have some links with this study that will also be discussed in light of the curricular models. Since the CT has no model of atom given to explain the concept of electron flow, the curricular model of atoms is not relevant for the content analysis of the textbook. The learning factors for *graphicacy* (a term used by Roth et al., 2005), or use of pictures, are beyond the scope of the current study.

The Ontario science curriculum for the grade six level does not provide curriculum expectations on the curricular model of the atoms, and perhaps due to this reason, publishers also provide sparse information or no discussion on this topic. The current literature review shows no research study available that was conducted on grade six level students in Canada which shows data on students learning or a textbook analysis of the curricular model of the atoms. The question is whether the influence of computer technology is also playing a role to inform students, and also which type of curricular model (orbit model, Bohr's model, quantum model or hybrid models) they prefer to learn from. The current literature review also shows meagre information on research studies conducted on this topic. While the science education reform is advocating for using the nature of science in the curriculum, the research studies have not collected data on the curricular models of the atom that also show representatives of the nature of science (RNOS), particularly in the Canadian learning environment.

2.6.1. Curricular model and student made models of atoms

Students prefer models of the atom that are relatively easily visualizable (cf. Harrison and Treagust 1996 and Justi and Gilbert 2000). Harrison and Treagust (1996) conducted semi-structured type interviews in their study and surveyed the mental models of atoms and molecules from 48 grade 8–10 students. Their study reveals that many students preferred models that are both discrete and concrete. Although modeling is a useful skill that defines much of the scientific method, the pedagogical challenge is that many grade 8-10 science students have difficulty separating models from reality. In this study by Harrison and Treagust (1996), students were given the opportunity to draw the atomic model of their preference. After this, they were shown six diagrams of atomic models commonly used for teaching this concept in the classrooms. Students had to select which diagram represents their model in the best way. Results show that 46% preferred the orbit model, 55% thought atoms are spheres, and 32% drew simple diagrams with a nucleus and electrons.

The analysis in the previous discussion based on the study of Justi and Gilbert (2000) and Harrison and Treagust (1996) shows some distinct examples of atomic models used as curricular models in the textbooks and student drawings. For example, the diagrams contained a nucleus in the centre and orbits outside to show the electrons, as well as more modern models with electron clouds in which the whole atom looks like a ball made of tiny dots. Justi and Gilbert (2000:1006) also point out the pedagogical need: "If students were mixing such different representations and reducing a very abstract model to a more simple and concrete one, this may be a result of the use of hybrid models in teaching." Relating this finding with the current study conducted on grade six students in Toronto, certain patterns are revealed. The textbook CT does not provide any model of atoms to explain the concept of electron flow. In the experimental group, out of 39 students, who made the picture of atoms to explain their written work, 33 of them tried to draw the three-dimensional view of electron orbit. The role of additional resources used is also compared with this feedback. Images of electron orbit are shown on page seven of the Parker (2005) book, pages 24 and 25 of the Whyman (2005) book, and page seven of the Peters (2000) book. Some publishers of these books have used diagrams that are a simplified, computer-made model, in which electrons zoom around the nucleus of an atom. Perhaps students were influenced by the additional resources they were exposed to during the learning process, and that could be a reason as to why those pictures are reflected in their written work. The models drawn by the grade six students are closer to the modern-style diagram of the atomic model, where electron movement is explained by the quantum model. Neither was the HPS factor for atomic models highlighted in the textual information presented in this study, nor have the students made any direct reference to it in their work.

2.6.2. Use of atom related explanation of electricity in science textbooks (Toronto)

Some **old science textbooks** used in Toronto show a similar trend with the lack of atom-related explanation of electricity (comparing all textbooks used in Toronto is not the aim of this discussion). Around 1954, a grade six level textbook was used in Toronto titled "Canadian Wonderworld of Science" (Knox et al.1954). This science textbook has about 47 pages on the topic of electricity. The sub-heading of the chapters include: Electromagnets, Using Electricity to Send Messages, Electricity for Heat and Light, The Science Club, The Science Fair. The explanation of atom related explanation of electricity is missing. Near the end, the textbook gives a list of 20 topics for further study and those topics include: Alternating current, Aluminum, Cablegrams, Carborundum, Direct Current, Electric Cells, Electrons, Electrolysis, Electroplating, Electrotyping, Elevators, Fire Alarms, Neon Lamps, Photo-Electric Cell, Submarines, Subways, Television, Transformers, Tungsten, X-rays. It is interesting to see how rapidly the growth of science and technology has transformed the priority of science textbook topics over a short period of time. Also, it is notable that the word "electrons" is mentioned in the topics for further study. When grade six students encounter the statements given in the textbooks related to the 'motion of electricity' and 'electricity is everywhere' it can be facilitated with the underlying activity of atoms and electrons to promote explanatory understanding to some extent. A grade seven science textbook used in Toronto around 1962 titled "Advancing in Science" (Partridge 1962) discusses electricity in relation to Heat and Electricity. However, the in-depth explanation of the concept of electricity is not included in this textbook. The textbook gives the name of specific encyclopedia for further reading. The need to supplement textbook learning is still an emphasis of research findings, such as Phillips (2006). The revolution of information age has also broadened the scope of supplemental information, though educators question the validity of some of those resources (Wellington 2001). Around 1962 a grade five science textbook titled ‘Science Activities’ (Hedges and Farewell 1962) was also used in Toronto schools. Although this textbook does not give details about ‘electrons’ to explain the process of electricity, it does however mention: “when electricity moves through a wire it is called an *electrical current*.” (Hedges and Farewell 1962:156). While discussing electrical charges it says: “When electrical charges are different they go towards each other if there is something that they can flow through” (ibid.:156). This statement needs further explanation to make correct meaningful connections. Another grade five science textbook titled “Seeds 5” (Hill et al. 1981) gives more emphasis on activity-driven learning. For example there is an activity called ‘the energy in a Carton of Milk.’ However, the concept of electricity is not a major focus of this book. Flanagan, et al (1983) published a textbook (grade five) titled ‘Focus on Science,’ and they have discussed the concept of electricity (p.31) in relation to atoms.

There are other books written for children about electricity—which are not textbooks—that apply strategy of explaining electricity using the concept of atoms with the help of text and pictures. For example, a recently published book titled ‘Electricity & Magnetism: A World of Electricity & Magnetism from Natural Sources to Electromagnets and Microchips with Projects to Explain the Science.’ The word ‘explain’ is mentioned on the title. This book uses the word ‘ELECTRON-ICITY’ and also describes ‘ELECTRONS ON THE GO = ELECTRICITY.’ (Parker, 2005:7). Perhaps this emphasis can be useful for grade six students to make connections between electrons and electricity. However, further research is needed to explore the understanding of students in this context. Whyman (2005) has used a picture to show a ‘free electron’ to explain the concept of electricity along with text. The connection between the general notion of electricity and atoms is also described in some encyclopedias, such as The World Book Encyclopedia (cf. March, 2006). There is the need to further test the learning effectiveness on grade 6-8 students. Due to many administrative reasons the use of textbooks becomes very important and access to other science books of children is not frequently possible in most of the situations. The examples of electricity and atom related explanation used in other science books of children can also be applied in children’s science textbooks, and empirical comparisons can be made. Further research is suggested to compare the learning effectiveness of this integration of conceptual notions versus comprehension tools.

2.7. Science curriculum patterns, education policies and textbook contents

In terms of elementary level science curriculum it is important to note there is no federal government level department of education in Canada; therefore, education is under provincial or territorial jurisdiction (Buteau 2009). There are ten provinces and three territories in Canada, which develop their own programs of studies and learning resources. The Canadian science curriculum has been changed significantly in the last few decades (Roscoe and Mrazek 2005). The older curriculum was primarily targeted to train a smaller group of population for post-secondary education for science and engineering-related programs (cf. Roscoe and Mrazek 2005; Roth 2001). With the changing trends in the world due to the rapid growth in science and technology, the curriculum of science is also changed with time. In keeping with international trends, Canada has also broadened the scope of science education in schools to address the future needs of students regardless of which population group they belong to. A brief comparison of traditional and revised trends in science curricula is shown in the following Table 1.

Table 1: Revised science curriculum and traditional science curriculum compared (Roscoe and Mrazek 2005)

Revised Science Curricula (Aimed at developing scientific literacy)	Traditional Science Curricula
For all students regardless of age, gender, cultural background, or career aspirations Broad-based goals: personal, social and academic Incorporate an STSE perspective; interrelationships of science, technology, society and environment provide meaningful learning contexts A broader view of science learning: interrelated outcomes, wider range of knowledge, skill, and attitude outcomes	For an elite group of university-bound students Mainly academic goals A focus on knowledge outcomes, Often with inappropriate learning contexts A narrow view of science learning: memorization of isolated facts and developing of a narrow range of science skills

The new trends are adopted and applied with certain variations in the provincial curriculum guides. In a broader sense, the personal goals of science education include learning to apply problem-solving as lifelong learners. Science education in Canada now also focuses on developing a sense of learning with curiosity to encourage an ever-exploring approach. The traditional focus of science is also continued to prepare students for science and engineering-related professions (cf. Roscoe and Mrazek 2005; Glyn et al. 1991). The following goals for science education are widely considered appropriate for science literacy in Canada: (1) to develop and foster a sense of curiosity among the students for science and technology; (2) application of science and technology to ascertain new knowledge and solve problems; (3) innovatively criticize environmental issues faced by our society; (4) preparing students for a higher-level study of science and work in related professions; (5) gain awareness about science and technology related job-market and careers (cf. Roscoe and Mrazek 2005).

The STSE approach for science education includes science, technology, society, and the physical environment. The STSE approach is also closely associated with the goals of the nature of science. Some common components include understanding science from a broader dimension in contrast to a fixed-facts memorizing approach. The STSE pattern includes developing a sense of curiosity within students. On the other hand, the NOS understanding model includes “science as a way of thinking” and there seems to be a link between the two approaches. The whole idea is to prepare students to learn science not for the mere memorization of facts, but to understand the concepts for a range of applications with a possibility to integrate new knowledge. In real learning situations, an ongoing challenge for educators and policy makers is to address the needs of all students in terms of their understanding of science concepts.

In order to apply the STSE approach, Pan-Canadian Science is an organization which provides direction from a central body to guide provincial curriculum designers. Buteau (2009) from the Canadian Counsel of Ministers of Education (CMEC) reports:

> Pan-Canadian science refers to a curriculum framework document that was developed by CMEC in 1998. All provinces and territories, with the exception of Quebec, participated in the project. The framework identifies a series of curricular outcomes from which provinces and territories can choose when they build their own programs of studies. The framework has been particularly useful in that it led to the development of teaching and learning resources that could be used in a good number of provinces and territories. The framework has not been updated since 1998. There is currently no Pan-Canadian curriculum collaboration project at CMEC. Other than the 1998 framework, there is no CMEC policy on science education.

The four key components of scientific literacy or foundations as explained by Pan-Canadian framework are (1) science, technology, society and environment (STSE); (2) Skills outcomes; (3) Knowledge outcomes and; (4) Attitudes outcomes.” (cf. Roscoe and Mrazek 2005). The four components of scientific literacy are designed in an attempt to find the linking grounds among the various learning outcomes. Roscoe and Mrazek (2005:15-16) connect the four components with the example of teaching the concept of electricity in the following way:

> The key consideration for scientific literacy is the development of strong links between the four foundations as students learn science in particular contexts. Rarely is one component of scientific literacy development in isolation from other components, and all four foundations can often be addressed in one learning activity. For instance, in a grade 6 electricity unit (Knowledge: Physical Science), a meaningful learning context such as electricity use in the school, enables students to simultaneously develop STSE outcomes (e.g., describe how discoveries in science enabled the development of new technologies such as energy-efficient light bulbs), skills (e.g., safely gather data on electricity consumption), knowledge outcomes (e.g., explain how electricity in circuits produces light), and attitudes (e.g., consider evidence before drawing conclusions, work collaboratively with others).

The arguments discussed above emphasize a multidisciplinary approach for science learning. On one hand, the integrated approach adopted to align the STSE, knowledge, skills, and attitude outcomes seems to be plausible for making science more relevant to the learners and to society. However, the effectiveness of explanation for grade-specific needs has to be coordinated in an integrated way (cf. Newton et al. 2002; Roth 2001). A possibility is to research further and experiment with various textual and cognitive models to make curriculum outlines and learning resources (especially textbooks) a reflection of theory, research, and practice. In the above mentioned example given by Roscoe and Mrazek (2005), the knowledge question is "how electricity in circuits produces light." Perhaps the explanatory aspect can be improved if the authors of textbooks take a step back to explain what electricity is, and then elaborated further in the following stages. The need for explaining the conceptual links from the initial level has been a point of discussion in many contexts in this study.

The provinces of Canada have developed their own curriculum guidelines and some indication of including Pan-Canadian frameworks can also be seen in the local level curriculum guides. In relation to this study, the topic of electricity is critically discussed to some extent in several of the provincial curriculum guidelines used in Canada. In the province of British Columbia, the curriculum guideline (Science K-7, 2005:108), *Integrated Resource Package* states:

> In this study, students gain a basic understanding of how electricity works. They explore the characteristics of static and current electricity. Students discover the characteristics of conductors, insulators, switches, batteries, light bulbs, and electromagnets. Students test, design, construct, and evaluate various combinations of circuits, switches, batteries and bulbs. Students examine the production and transmission of electricity in British Columbia.

The outlines given above indicate an integrated model which is closely linked with the Pan-Canadian framework for science education. A clear emphasis on environmental issues is not mentioned in the quote given above. The explanatory understanding goal can also be envisaged by constructing concepts on what is electricity instead of only focusing on how electrical devices work. The British Columbia Ministry of Education has also included a heading on vocabulary. Perhaps the rationale is to integrate the unit learning along those lexemes. That vocabulary list includes the following words: atom, electron, static electricity and current electricity, electrical current, closed and open circuit, conductor, insulator, battery, magnetism, parallel circuit, series circuit, switch, voltage, geothermal, nuclear, tidal, solar, wind power, biomass power, coal gas, fossil fuels, hydro, hydro-electric dams, renewable, non- renewable, consumption, conservation, electrocution, direct current, bulb, positive, negative, electrical energy. Many of those lexemes are a common focus of learning in the Ontario curriculum, however the lexemes "atom and electron" are mentioned in the

British Columbia curriculum outline. The British Columbia curriculum outline "science K to 7" also includes the information that "static electricity is the result of the accumulation of excess charge on an object" and "an electron is negatively charged particle." The inclusion of lexemes which promote in-depth reasoning beyond the everyday use of electricity is a step closer to explanatory understanding. How well those ideas are explained in various geographical locations using the textbooks and other classroom resources is a question that would need large-scale, inter-provincial study in Canada. The Atlantic provinces of Canada (which include the provinces of New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador) have also emphasized the effective use of curriculum resources (textbooks are part of it), including additional resources as it affirms:

> Even with the advent of new media, print materials remain a dominant type of resource for science teaching and learning. There are a number of categories of print materials available to science teachers and students—teacher reference materials dealing with science teaching, student textbooks and accompanying teacher resources, science activity books containing ideas for experiments and/or demonstrations, science trade books and reference books (e.g., science encyclopedias), and supplementary science books that augment or complement science textbooks.

The use of the textbook in conjunction with additional resources is also compared in the experimental group of the current study. The effectiveness and some aspects of comparisons are given under the subheading 3.7 and 3.7.1. The variety of literature currently available for children discusses science topics from a range of genre perspectives. From a broader perspective, the general use of such literature is increasing (cf. Walker and Huber 2002; Rowell and Ebbers 2004), while the cognitive outcomes which emerge as a result of the interface of textbooks and other materials needs intense theoretical and empirical research (cf Lee 2007; Rowell and Ebbers 2004; Koulaidis and Tsatsaroni 1996). Roscoe and Mrazek (2005) consider science, technology and environment issues as a related problem. Since the conceptual links extend from one aspect to the other, perhaps it will be useful to show the interconnecting linkages between various groups. For example, the "scientific inquiry" can also extend to the dimensions of technology as to how and why it happens when certain inventions are made. In this view, the distinction of energy transformation and energy transportation can be distinguished to facilitate the concept formation process, as many textbooks and other resources do not clarify this precise distinction. The NOS factors can also be aligned in this approach to make classroom program plans and textbook designing enriched. For example, the links between NOS and HSE, the ever-changing nature of science knowledge, and the application of the scientific method can be more clearly integrated in this approach.

The need for explanatory contents, textual information enhanced with graphics to highlight the scientific reasoning is a factor which is also a concern for the curriculum and elementary level science textbooks of Pakistan. From the research studies published on textbooks from Pakistan, Mahmood (2006) and Mohammad & Kumari (2007) have highlighted the need for improving information provided in the textbooks, curriculum presentation factors and textbook designing problems. Due to ongoing social changes, the elementary level science textbooks/curriculum designing is in need of review and update (cf. Hoodbhoy 2012; Mahmood 2006; Mohammad & Kumari 2007). Those studies from Pakistan also highlight growing need to improve the elementary science level curriculum and textbooks to include explanatory models, reasoning behind the everyday observations, science and other subject links. Within the textbooks the need for applying "elements" and "linkages" for stronger text models is also crucial, as described by Chambliss and Calfee 1998. Another important factor is the use of graphics to explain the textual information as described Roth et al. (2005).

2.8. Elementary level science textbooks for science as fixed-facts knowledge and science as changing knowledge

Cohen (1988) compared science as something containing fixed facts and free from human deformation. This is something we have taken as a given truth. In other words, what we teach in science to our students is delivered as something totally correct or fixed fact, while the changes or innovations or distortions are not taken into considerations. Caswell and Bielaczyc (2001:282) conclude:

> What if, instead, learners came to see the current state of knowledge in the sciences as tentative, as progressing through continual refinement and problem redefinition? What if students came to understand the purpose and power of replicability for building knowledge in the science, as opposed to carrying out and repeating experiments as part of schoolwork required to satisfy the teacher. Such a shift in students' perspective on scientific knowledge is critical.

Caswell and Bielaczyc (2001) have collected data through the use of a computer program "Knowledge Forum". The focus is on grade 5/6 students and their view of scientific knowledge and the meaning of learning science. Katherine Bielaczyc from Harvard University and Beverly Caswell from the University of Toronto have published a study "Knowledge Forum: altering the relationship between students and scientific knowledge." In the research paper, Caswell and Bielaczyc have discussed the possibilities for altering the relationship between students and scientific knowledge. Traditionally, science is seen as set of given definitions, concepts and theories where students are more on the receiving end. Hartman (2001:185) concludes:

> Awareness creates cognitive conflict which motivates conflict resolution to accommodate current beliefs or cognitive structures. Accommodation may lead to modifying existing structures and/or creating new ones. Minstrell (1989) claims that earlier ideas are seldom pulled out and replaced. He

> believes it is more effective for teachers to help students differentiate between their present ideas and those of scientists and to help them integrate their ideas into conceptual beliefs more like those of scientists.

In the real world of science, it is common to observe the changes even in the views of scientists, which brings more challenges for the writers of contemporary children's textbooks. However, training students to keep their minds open for change or innovative application is a possible option. In the "Knowledge Forum," model students are engaged in doing some experiments and they contribute in producing results. According to Caswell and Bielaczyc (2001:302), "students also come to see that their ideas are worth something, that they have views to contribute to the evolving overall understanding." In this model students take more responsibility in their own learning, and they work at a greater level to meet the goals of the curriculum. Newton et al. (1999:556) suggest:

> Traditionally, science teaching has paid little attention to argument and controversy. This has given a false impression of science as the unproblematic collation of facts about the world, thereby rendering disputes between scientists, whether historical or contemporary, puzzling events.

If the history of science is critically compared, some of the older theories may appear like a mistake in the light of our current theories. The scientific knowledge goes through ongoing growth, changes, and testing. As Gregory (1981:142) explains:

> The word 'electricity' (coined by William Gilbert in 1600) comes from the Greek for 'amber' (ektpov), whose properties of attraction were known to Thales in the sixth century BC. The magnetic properties of electricity and magnetism are curiously lifelike, and have often suggested analogies between Natural and Unnatural that have generally proved deeply misleading. On the other hand, electrical (and very recently also magnetic) properties of neutral activity have turned out to be essential keys to understanding the physiology of the nervous system.

How our understanding of insulators and conductors has shaped to our current state of distinction has gone through some critical phases of experimentation. According to Gregory (1981:143):

> Particularly interesting experiments were performed in Paris by Charles du Fay (1698-1739), who reported to the Academy of Sciences in 1733 and 1734 that all bodies could be electrified, whatever their substance. This disapproved the earlier notion of Jean Desaguliers that some bodies are 'electrics' and others 'non-electrics,' for du Fay found that 'non-electrics' are conductors of electricity and may be electrified when insulated.

A comparison of science textbooks from a historical perspective can reveal some of those changes or certain limitations. When a textbook presents a specific idea for children, the common practice is to explain only the most current idea. Even a brief history of the changes in that concept, theory, or idea is generally not given in our school textbooks. In order to keep the choices open for future changes (as discussed in the *Knowledge Forum*) and promoting innovations, inventions and paradigm shifts, the science textbook for elementary students can examine the possibility of including the history of the development of science-related ideas. Students can be encouraged to think of possible changes and innovations to our existing knowledge within certain limits of curriculum delivery challenges. Perhaps an interdisciplinary approach by scientists, linguists, educators and cognitive science experts can lead to a curriculum that is based on cognitive exploration. Thus, a textbook can explain the scientific concepts, and the overall learning environment can show historical changes of scientific ideas and leave the doors open for future hypothesis. Students can experiment in the interdisciplinary fields and contribute to knowledge by developing and applying their skills. This approach will inform elementary school level students that science is not just fixed facts, but new research and innovation are a possibility, as discussed by Caswell and Bielaczyc (2001). Our traditional way of teaching science and textbook designing has close link with our understanding of science. Newton et al. (1999:555) conclude:

> Observation and experiment are not the bedrock upon which science is built; rather they are handmaidens to the rational activity of constituting knowledge claims through argument.

There is theoretical and experimental evidence that shows common trends in the explanation patterns of children and scientists. According to Keil and Wilson (2000: 289) “children’s explanations for the physical world show the same essential structure as those used by scientists, except that scientists include a requirement that explanation be potentially testable.” By connecting the standpoint of Caswell and Bielaczyc (2001) with Kiel and Wilson (2000), one can argue the design of textbooks using proper “elements and linkages” can facilitate interdisciplinary explanation of science and encourage students to form and apply their own hypothesis.

In some countries, the textbook works as a major guide for students and teachers (Farrell 2001; Johnsen 1993). While some countries use technological and traditional resources concurrently, others have a lack of available resources. A technological-based tool such as *Knowledge Forum* is not commonly available or used as a learning resource even in the Toronto classrooms. This tool is also not used in the schools of Pakistan in which the study was conducted.

The idea behind *Knowledge Forum* research puts an emphasis on altering the relationship between students and scientific knowledge, and it also promotes students’ contribution to knowledge (Caswell and Bielaczyc 2001). The research driven by *Knowledge Forum* has its own value if it is applied properly and the improvement of current classroom resources is a different type of challenge. Overall, textbooks can attempt to bridge this gap in many ways. For example, textbooks can design knowledge delivery text and pictures along with the possibility of encouraging new research and inventions. Textbooks can also reinforce a learning environment to redefine, re-examine, and make new hypothesis in the light of *Knowledge Forum* data. In order to encourage innovation and keep minds open for new theories, students have the opportunity to be exposed to older textbooks, and observe how our knowledge and meta-cognition has transformed over a period of time.

The question arises: Can every classroom environment apply the *Knowledge Forum* model in the given settings? It is still a big challenge to bring such tools in the schools of Pakistan. Comparing the case of Ontario, where the curriculum revolves around given "expectations" and certain time constraints, other challenges can limit the possibility of conducting experiments, exploring, and contributing their knowledge. Teachers and students also need some training to transform their thinking from conventional science learning (knowing fixed facts), to exploring through experiments and sharing their knowledge. However, due to the accountability in the public school system (education policy), some fixed structures of science knowledge will remain in place to meet specific goals for all students. How flexible are our textbooks when it comes to encouraging innovations of the readers? Can we apply the *Knowledge Forum* model through our textbook use? The innovative and ever-changing form of science knowledge is not possible just by providing students some possibilities to explore and discuss. We must also modify our whole approach for science learning and teaching. From a logical standpoint, the notion of limit stays even in the theoretically limitless approach to explore. According to Redhead (1990:135):

> The ideal of scientific explanation is a matter of logical deduction, given a unified set of deep explanatory principles that are themselves accepted, for the time being, without explanation. But of course the ideal of scientific explanation is one for ongoing improvement. Perhaps from the fundamental laws of microphysics, by some consistency criterion, it will turn out that the constants of nature are tightly considered or even uniquely determined. But even then we would still have the task of explaining the laws themselves at a still more fundamental level. At some stage scientific explanation always turns into description.

When it comes to finding the nature of electricity by exploring the flow of electrons, there are many challenges related to resources, the children's ability to understand highly abstract notions of scientific concepts, and our current teaching models. In many school systems, the teaching is heavily based on *outcomes* or *expectations*, and the goal is to meet them in a given time frame. More research is needed to examine our curriculum expectations or outcomes in terms of what emphasis is given to the element of innovation and ongoing changes in science. How far are students allowed to go to contribute their knowledge, as opposed to just receiving knowledge within their capacity (*Knowledge Forum* research)?

The Ontario science curriculum provides consolidated expectations ("by the end of Grade 6 student will"). On the topic of electricity for grade six, it provides opportunities for students to acquire skills to perform inquiries on comparing the uses of electricity, and energy use in the past and present. However, it does not include in that section factors related to human distortion, changes in scientific theories, and future inventions, as discussed in the *Knowledge Forum* data collection.

2.9. Evaluating students using textbooks beyond right and wrong dimensions

Chiu and Lin (2005) have also placed emphasis on teachers' awareness of their own learning process. On the other hand, Wieman has also linked this to the evaluation process of students' learning. Wieman promotes the use of meaningful evaluation by closely observing how students complete a task (Backhouse, 2007). This approach is close to the cognitive task analysis approach by examining common errors and filling the gaps in the following lessons. Mayer (2003) has given an example of finding common errors in the students' work, not in terms of giving marks in the conventional way by looking at the percent of correct answers, but to look at common errors to work on upgrading those skills. Wieman explains this in these words: "For effective learning you really have to understand student thinking and then you've got to provide timely, targeted feedback to help guide that thinking. Technology enables you to do things you couldn't possibly have imagined in the past" (Backhouse 2007:20). Textbook designing, curriculum resources, and teacher training can incorporate this dimension in the learning process. Error analysis of students' responses provides some possible pathways to explore the missing leads in the process of concept formation (Hartman 2002). Many teacher guides written to supplement the textbook do not use the analysis of common student errors, and the traditional way of finding the right and wrong answers still prevails. The teacher's guide written for the electricity textbook that was analyzed for this study also gives a review test from the conventional approach to find the right or wrong answers, while the analysis of the common pattern of errors in the students' work is not emphasized.

One of the prime goals of textbook designing is to promote conceptual learning and understanding (cf. Chambliss and Calfee 1998; Peacock and Weedon 2002; Hubisz 2001). Hall and Greeno (2008) have recently discussed the issue of knowledge transfer in relation to cognitive abilities. A common view of concept formation and understanding gives more attention to the process of transfer. The frequently used testing and evaluation methods can present data which shows that students have learned a concept based on the correct answers given by students. The bigger challenge is when those students are given problem solving questions which differ from the particular instructions given. In many instances, the responses of students show gaps in concept attainment (cf. Newton 2003; Roscoe and Mrazek 2005; Roth et al. 2001). According to Hall and Greeno (2008:219):

The problem, according to the mainstream view, is that they failed to transfer knowledge they had acquired to the novel situation. Perhaps the knowledge they acquired lacked the generality that it should have had, or perhaps they did not acquire needed procedures for instantiating their general schema in the kind of situation that was presented in the transfer test. In the situational view…knowing a concept is not considered an abstraction from practice; instead, all conceptual understanding is assumed to be embedded in social practices….knowledge of a concept is not assumed to be inherently general or specific. Instead, in activities that potentially could be informed by a concept, communities' or an individual's practices vary in their extent of affording use of that concept (or concepts) in a broad range of settings.

The conceptual gaps are not only the result of textbook learning as the learning environment is composed of multiple factors. The role of the textbook can take into account the possibilities of showing exemplars to promote cognitive maps for the new situations of the same problems. Perhaps this process will facilitate the learning environment in two ways: teaching conducted by non-specialist teachers can benefit from higher-level applied problem solving exemplars, and students with the lack of opportunity to transfer knowledge may find it difficult to apply science concepts in problem solving modes. In order to analyze this process from theoretical, research, and practice dimensions, further research is needed to focus on knowledge transfer issues in specific parameters.

2.10. Metacognition awareness in the textbooks

For over twenty five years educators, linguists, psychologists and others have been exploring the role of metacognition from theory, research and practice perspectives (Hartman 2001; Torrance 2006; Mintzes; Wandersee; Novak 1998). The commonly understood difference between cognition and metacognition is that cognitive skills are set of required skills to perform a task while metacognition deals with the understanding of how a task is performed (Schraw 2001). Constant practice and reflecting on the learning process promotes metacognition awareness (Siegler and Jenkins 1989). According to Schraw (2001:8), "studies examining the construction of theories of mind also suggest that reflection, both as a solitary and group endeavor, contributes to the breadth and sophistication of such theories." It is an important observation that many textbooks written for grade six students and designed for curriculum outlines miss an opportunity to reinforce the metacognition factors.
Hartman (2001:198) remarks:

> Metacognition helps science learners develop and use effective and efficient strategies for acquiring, understanding, applying and retraining extensive and difficult concepts and skills. Good science teaching requires teaching both with own metacognition and for the development of their students' metacognition.

Textbooks of elementary science are in the very early stage of applying the use of metacognition awareness model in the text or graphicacy. Hartman (2001:179) also suggests another tool to facilitate metacognition: “Concept maps and Vee diagrams help people learn how to learn.” Conceptual map-patterns of various learners can also be used to trace the metacognition process to some extent.

A well-integrated approach on metacognition awareness in textbooks and curriculum outlines can lead to expand the scope of learning potential of various students. How scientists go through the process of invention/discovery or the meta-cognition is normally not discussed in conventional science textbooks. What effect is made on students’ learning if the stories of the process of inventions are shared? How do scientists go through the metacognition process? Research is needed to explore the answers to the above questions in order to incorporate those strategies in the designing of the textbook.

Wieman puts emphasis on “meaningful assessment methods” (Backhouse 2007), while the use of such methods in relation to metacognition awareness can also reinforce the development of cognitive skills. Hartman (2001:149) remarks that “teaching metacognitively involves teaching *with and for* metacognition.” What does this mean for textbook designing? Since textbooks are prevalently written to meet the demands of curriculum and/or sale demands, the metacognition-based design of textbooks has close links with the interest of all stakeholders. Barba et al. (1993) explains that metadiscourse commonly involves the author using sentences to speak directly with the reader to make connection in relation to a topic, such as “remember we did an experiment related to this topic.

Further research on resources and the training of teachers, as well as all other influencing variables of science education and pedagogy are necessary in order to incorporate the metacognition awareness paradigm in the actual classroom practices.

2.11. Real world science challenges in comparison to real challenges of the classroom

Carl Wieman, a Canadian Nobel Laureate in the field of science (Physics) says: “Science is about understanding the real world, but the real world is not really the best way, pedagogically to explain many of these ideas” (Backhouse 2007:21).

In the case of teaching on electricity, on one hand it is difficult to show the actual flow of electrons to explain the phenomenon of electricity, while the use of analogies, diagrams, and computer-based models can facilitate the learning of some complex concepts (cf. Chiu and Lin 2005; Mandl and Levin 1989).

The use of analogies, concept maps, and refutation texts also facilitates to understand the reasoning process, and promotes the understanding of difficult concepts (Diakidoy; Kendeou; Ioannides 2003; Mandl and Levin 1989; Harrison 2001). The additional resources used for this group also included diagrams on the electron movement, atoms, and other related graphic details. Perhaps it is due to this reasons that the students' responses in the experimental group show some indication of reflecting more electron-related conceptual links, as compared to the control group. This inference, based on a limited-scale experiment, also shows the possibility of inculcating an atom-related concept of electricity to grade six students, as compared to simply discussing the observation of electricity use around us. Harrison (2001: 403) concludes that "analogy is an effective way to explain unfamiliar ideas providing the explainer and the listener understand the analog in the same way." Although the focus of the current study of textbook analysis was not on the effects of analogies, a study conducted on the use of analogies on grade four students on the topic of electric circuits by Chiu and Lin (2005) shows the benefits of using analogies to teach the topic of electricity. Chiu and Lin (2005:429) conclude from their study:

> The results demonstrated that using analogies not only promoted profound understanding of complex scientific concepts (such as electricity), but it also helped students overcome their misconceptions of these concepts. In particular, we found that the reason the students had difficulty understanding the concept of electricity was because of their ontological presupposition of the concept.

The study of Chiu and Lin (2005) gives strong demonstration of applying analogies to teach the concept of electricity to elementary-level students. The use of analogy can work to facilitate the understanding of challenging concepts for elementary-level students. Chiu and Lin (2005) provide four recommendations based on their study of teaching the concept of electric circuits to grade four level students. Curriculum developers use well-planned analogies to facilitate the learning of difficult concepts. Analogies must match with the attributes and relationships of the prospective concept to promote clarity in understanding. Analogies may serve as a source for another type of conceptual frame. Therefore, the use of more than one analogy can be more useful to make conceptual links. Science teachers can be introduced to understanding and recognizing the difficulties of their learners so that they can develop meaningful analogies for matching concepts, as well as analogies to promote coherent mental representations. Despite the usefulness of analogies, teachers must use multiple analogies with care to avoid abuse of analogies.

The research study of (Chiu and Lin 2005) has implications for textbook designing and curriculum development. Despite the emphasis by the pedagogical researchers this need is not yet incorporated in many textbooks (cf. Roth 2005; Mandl and Levine 1989; Harrison 2001). The textbooks CT and PT that are analyzed for this study have also missed an opportunity to bring explanatory understanding in the text and pictures by using analogies on various themes of electricity (explained in detail under under sub-headings 5.2 and 5.5). As discussed previously, textbook publishers mostly try to meet the supply and demand formula in order to maintain a sound reputation in the business (Giordano, 2003; Johnsen 1993). In many cases, it is just to give a feeling of complying with the demand of textbook users. The higher demand shows the need that can be transformed to make an impact to bring some changes in the textbook designing by enhancing the use of analogies and diagrams along with the plain text to facilitate links between real-world science to classroom science. This process can initiate an environment of change to improve textbooks by using analogies and various modes of visual communication to enhance effective learning. The other level of using more analogies to explain difficult concepts is linked with teachers, curriculum designers, policy makers and other related professionals. The application of the explanatory model to enhance explanatory understanding in the textbook designing is a question of combining theory, research, and practice in the most meaningful way.

2.12. From textbook analysis to developing overall curricular application for history and philosophy of science (HPS), nature of science (NOS), and cognitive science

The current research trends in science education, textbook analysis issues, and education policy focuses are moving toward a vigorous model of the nature of science (NOS) and closely related fields. In a very recent study, McComas (2008:249) asserts that “increasingly widespread agreement exists that the nature of science (NOS) must be an integral element of the K-12 science curriculum with emerging consensus on what specific NOS elements should be the focus of such instruction.” From the interaction with some frontline teachers, it appears at present that many individual elementary level science teachers stand at the juncture of knowing what the history of NOS itself is, and how it will be different from what is currently offered before moving further. Some teachers who participated in this study expressed their discomfort on understanding the nature of science themes. It was widely seen by them as linking science and society while the way science works was not considered a topic of learning for grade six level students. The multiple nature of science is more than science and societal interaction. McComas (2008:249) discusses the multiple facets of those domains as follows:

> There is little doubt among those interested in science curriculum reform that a robust and authentic science program must contain elements of the nature of science if students are to understand and appreciate the scientific enterprise both as content (the facts of science) and process (the generation and testing of truth claims in science). The nature of science (NOS) is closely related, but is not identical, to the history and philosophy of science (HPS). As used here, NOS is defined as a hybrid domain which blends aspects of various social studies of science including the history, sociology and philosophy of science combined with research from the cognitive sciences such as psychology into a

> rich description of science; how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors.

From the perspective of frontline teachers, the need to go beyond the history of science has some other notion as to what is the history of science education (HSE). They question what is the “why” and “how” for bringing in the wider approach of NOS in the curriculum. By conducting this study on textbook analysis, interacting with teachers and students, an important need appears to incorporate the nature of science education (NSE) in teacher training programs to enrich the emerging contents of the nature of science (NOS). One can argue on considering the history of science education (HSE) as part of the nature of science (NOS). However, the domain-specific factor can facilitate to distinguish among the growing parameters of a relatively newly developing curriculum field. According to Osborne et al. (2011:631) "research would suggest that little space is commonly devoted to any explanation of how we know what we know within formal science education.....the predominant focus of classroom discourse is on ...... constructing causal accounts of phenomenon." This recently published work also supports the argument made about NSE. By providing students an opportunity in the textbooks and other learning interfaces, students may have more options to explore the notion described by Osborne et al. (2011).

Teacher training programs are already constrained with time pressure (cf. Richardson et al. 2001), and new teachers may need to distinguish between the goals of the nature of science and science education research shifts, in order to better specify textbook roles and the process of delivering the curriculum content. Teachers are also invited by publishers to write textbooks, as the case of the textbook CT shows from this study. Therefore, teacher training itself has to accomplish learning tasks on the themes of the nature of science and the history of science education. This dovetailing process can perhaps facilitate the teaching, and textbook designing field in multiple ways. The theoretical base perhaps favors this process to facilitate teacher training with the intrinsic details of the learning environment and their subsequent links with the nature of science (NOS). According to McComas (2008:250):

> NOS knowledge is not particularly accessible since the most complete and accurate description of how science and scientists function comes from a synthesis of the work of experts in the philosophy of science, the history of science, sociology of science and the psychology of observation. However, many of the descriptions, recommendations, concerns and analyses offered by those who examine the scientific enterprise are vast, deep and occasionally incomprehensible. As a result, the recommendations and descriptions coming from NOS experts as reported in original sources are not in a form appropriate for immediate inclusion in the K-12 science curriculum.

The collection of empirical data on the NOS and NSE approaches is a question that can be addressed in the future studies. Science education has also gone through many phases of development and knowing about them can be an enriching factor for teacher training or curriculum resource development. Tamir (2000:825) concludes that "no other area has grown as rapidly as the area of alternative conceptions." For example, if we look at the trends of research journals in science education, based on the number of entries in the ERIC database containing science education terms per every 10,000 entries, it was discovered that from 1966-1970 the entries on "conception" were only 14, which jumped to 123 around the period of 1991-1995. Constructivism was not seen as a research entry in 1966-1970, and this topic gained interest in 1991-1995 to 233 entries in the same group on ERIC (White 2001:459). The nature of learning also shifted from reception, rote, recitation, algorithmic reasoning, and memorizing facts to discovery, meaningfulness, constructivism, critical thinking, and problem solving (cf. Tamir 2000). What was the rationale for those research interest shifts? What does the history of science education inform us about those conceptual shifts? There is not much emphasis on this theme in our current teacher training programs in Canada, and the researcher presents this idea for future research studies based on the feedback of the study on textbook analysis. The teacher training programs need to address this question and other research-based practical strategies to better prepare frontline teachers to apply the research outcomes (cf. Harman and Glasgow 2002; Roth, Tobin and Ritchie 2001). When a teacher is using or selecting a textbook as the main source of learning in the classroom, the HSE may prove to be useful from a logical standpoint as it will enhance the need for introducing NOS. Teachers can make more informed choices based on knowing the rationale for changing science education trends (cf. Tamir 2000; White 2001), especially in the context of the history of science education (HSE) connections with the nature of science (NOS). Nevertheless, direct empirical research evidence has yet to show the link between HSE and NOS.

2.13. Understanding science concepts and the themes of science

The nature of science is also studied from the perspective of quantitative (cf. Phillips 2006) and qualitative domains (cf. DiGiuseppe 2007) in the research studies. The quantitative methods of analysis have placed emphasis on statistical indicators of the nature of science factors in science textbooks using the scoring procedures of Cohen's Kappa and Krippendorf's alpha. Phillips (2006) has used four strands of the nature of science: science as a body of knowledge, science as a way of thinking, science as way of investigating and science interaction with technology and science. The focus of exploring the balance of the nature of science needs more specified categories. In general terms, and from a semantic position, what encompasses "science as a body of knowledge?" This category is very broad due to the imprecise manner of the title, which can include other categories of this classification, therefore making it difficult to clearly distinguish the other strands. Perhaps further classification and labeling can be revised for clearer understanding. If the themes of the nature of science do not provide clear understanding in the minds of teachers and textbook authors, then it is difficult to assume that the concepts will be distinctly inculcated.

Alshamrani (2008:48) refers to Phillips (2006) with the argument "although Phillips (2006) shifted the use of these four categories from classifying scientific literacy to NOS, she did not provide an explanation to clarify why these categories were used as identification for both scientific literacy and NOS." This discussion shows the basic clarification needed to develop the parameters of the NOS application and analysis in textbooks and curriculum expectations. Phillips (2006:vii) also points to the imbalance found in her study: "This imbalance is providing students with only a rudimentary and fragmented view of how science works." In a more logical framework, what constitutes an imbalance has to come from the comparison of two or more components. If the imbalance is on the view of presenting how science works, then the other aspect it is imbalanced with needs more vigorous formulation, analysis, and curricular implementation. The statistical indicators is one aspect of textbook analysis and the learning environment needs more inclusive reflection of NOS, HPS, and cognitive science. Otherwise we will be exploring a broad field of NOS by one simple numeric indicator for which increasingly overlapping parameters may not give adequate information. The wide scope of NOS refers to HPS, science ideas development processes, science and society, science and technology. Roscoe and Mrazek (2005:16) remark that "science is therefore both a body of knowledge about the physical and biological world and an inquiry process for producing knowledge." The question is whether the publishing industry can provide the history of development of all science-related topics in the textbook and address the statistical balance of NOS entries, or will it only be a selective model for emphasizing on a few topics with a specific aspect of NOS. For example, in the analyzed textbook CT there are instances of Luigi Galvani from 1786 and Alessandro Volta from 1796, which discuss the discovery of electricity and the invention of the chemical cell. The teaching of NOS needs more specific structure to explore and compare how much of each NOS focus is desired for each level. Based on the analysis of NOS using the intercoder agreement with Cohen's kappa, some recent studies are showing more inclusion of the themes of NOS. Recent research by Chiappetta and Fillman (2007: 1863) explored that:

> High school biology textbooks are major curriculum resources that provide the subject matter content for a greater deal of what is taught in biology classrooms, and to some degree how the content is taught. From the analysis of five biology textbooks, three of which are the most widely used in the United States, there appears to be a reasonable balance of the nature of science themes that can be recognized in the writing and activities. The textbooks frequently encourage students to investigate, whereby they are directed to think about a phenomenon or situation, respond to questions, or gather information. Teaching biology as a way of investigation even surpasses teaching science as a body of knowledge, where biological concepts, principles, and theories are presented, which was not the case about 15 years ago when many high school biology textbooks were examined. Further, most of the five biology textbooks examined in the present study place a reasonable

> amount of emphasis on science as a way of thinking and how science is influenced by technology and society.

The statistical indicator of four aspects of NOS (science as a body of knowledge, science as a way of investigating, science as a way thinking and science and its interactions with technology and society) through the use of the intercoder agreement (cf. Chiappetta and Fillman 2007) is one step in this direction. Results as to how well those indicators have worked to deliver the textbook contents to the learners also need more data to make cognitive domain-related comparisons. The study mentioned by Chiappetta and Fillman (2007) indicates that the contents found in the textbook on frequently engaging students in the scientific investigation process leads to some improvement. The next challenge for cognitive science, educational linguistics and educators is to explore how well those statistical indicators can effect the understanding of the overall goals for NOS, HPS, and other related fields. Many studies reported on NOS in the recent past are about the analysis of the themes of the nature of science in high school science textbooks (cf. Alshamrani 2008, Phillips 2006, Lee 2007, Chiappetta and Fillman 2007), and the research on the use of NOS in the elementary level textbooks has obtained limited attention (cf. Lee 2007).

The effects of NOS on the students can be analyzed in future research studies in this field. How elementary level classrooms are linked with the secondary level and the real world of science and technology is characterized by Fensham and Gardner 1994:167):

> Perhaps the most promising future home for the idea of technological capability is in the primary school. Here, just one teacher is involved per class and the social barriers to co-operation [across subjects] in secondary school do not apply. Primary teachers live in the same technological world as their students. They may hence be less inhibited in trying to teach about its examples than they are by their strong sense of not knowing about the physical science—subject areas most of them chose not to include in their own education.

In order to make more specific use of the terms “primary school” and “elementary school,” it is noted that the province of Ontario uses the term “elementary” for junior kindergarten to grade eight, and the student age ranges from four years to approximately fourteen years. It is the grade six, seven, and eight level that is at the relatively higher elementary level, and also commonly referred to middle school. This age group may not be considered elementary level in some countries. The number of studies conducted on the themes of the nature of science for grade six level textbooks in Canada does not encompass enough data for critical comparisons with other similar studies.

Fensham and Gardner (1994), show the logical standpoint for the elementary level science and the technological experiences of the learners and educators of that learning environment, as described in the above quotation. The use of the nature of science themes can be integrated in some way at the elementary level and tested for the continuum in the high school level textbooks and student learning responses. This discussion opens doors for many future studies on finding links between the themes on the nature of science in elementary level textbooks and the high school textbooks and how those themes work for students' conceptual changes.

2.14. Construction Integration Model (CI Model) and Textbook designing

Students at the elementary level and middle school level encounter comprehension difficulties when using a science text for a number of reasons, ranging from word-decoding difficulties to the challenges of applying effective reading strategies (cf. Best et al. 2005; Gould 2003; Chiu and Lin 2005). Deep comprehension involves "more than mere interpretation of individual sentences; the reader must also be able to integrate individual sentence meanings into a coherent text-level representation" (Best et al. 2005:66). This also means the reader has to "construct global meanings" to join the meanings of various sentences. If a textbook analysis only focuses on sentence structures, the results may not provide enough evidence for overall comprehension patterns. The use of sentence analysis complemented with other methods of analysis can perhaps provide data for multiple comparisons with language and explanatory understanding. Making inferences is an important feature of understanding the text because it is the inference process which makes coherent meanings of various pieces of text, such as sentences, and pictures (cf. Kintsch 1998; Best et al. 2005; Roscoe and Mrazek 2005). The way sentences make an interrelated meaning out of sentences is exemplified by Best et al. (2005:66) in the following way:

> Consider the following sentence pair: (1) Plants lack a nervous system. (2) They cannot make quick responses to stimuli. The first inference that must be made after the first sentence is that the pronominal referent for "they" is "plants." Comprehension also depends on inferring that "the ability to make quick responses" is somehow related to the "nervous system." Building this inferential connection requires the use of logic, syntactic knowledge, and the ability to access knowledge from semantic memory, or to recall relevant information cited in earlier parts of the text. This form of inference is called a "backward causal inference" because it involves attributing the cause of a phenomenon or event described in a given sentence to a thing or event described in a previous section of the text. In the current example, successful deep-level understanding of this passage requires the inference that the nervous system is responsible for quick responses.

The backward causal inference process is a micro-level application of the students' previous knowledge, which can range from previous grade-level learning to the previous moment of reading a new sentence. The above example and analysis emphasize that deep-level text understanding is more than decoding words, knowing vocabulary, and apply syntactic skills. The in-depth comprehension also requires making connections between various sentences of the text and drawing meaningful conclusions. Kintsch (1998) provides a construction integration model (CI Model) which emphasizes on readers to first use their language-related skills, such as morphology, syntax, semantics, to construct a meaning on the basis of what is explicitly given in the text and then to move beyond to purely text-level understanding, to extract meanings from previous knowledge. The next level is to integrate more in-depth or comprehensive construction of mental representations which are intended to be conveyed by the text (cf. Kintsch 1998; Best et al. 2005). According to the construction integration model (CI Model), comprehension can be enhanced if text cohesion is improved, because this will partially decrease the need for making inferences (cf. Best et al. 2005:67). The text design with improved cohesion can possibly reduce some need to make inferences, but it will not completely eliminate this process. The science text in particular has vocabulary and conceptual issues for comprehension. Many elementary level students have difficulty in making inferences because they do not have a clear understanding of the concepts of science (cf. Gould 2003; Best et al. 2005; Roth et al. 2001, Braaten et al. 2011). If the students do not have prior knowledge of the science vocabulary the coherent meaning construction becomes an even greater obstacle in understanding (cf. Best et al. 2005; Chiu and Lin 2005). The authors of this study on deep-level comprehension (Best et al. 2005) have provided the support obtained by the use of a computer program called iSTART on the comprehension of texts. Two important conclusions from this discussion are to apply text analysis tools to identify the needs of readers to match the text to their level. The other possibility is to teach students how to read for understanding by using methods as comprehension monitoring, paraphrasing, elaborating, bridging, and self-explanation reading training. If the process of teaching elementary level students how to understand the text is compared with the real challenges of the classrooms, particularly in Toronto, the issues around practice and policy also needs consideration. The timeframe for teachers to cover a range of subjects and curriculum expectations results in integrated teaching modes. Situations of such time constraints can transform teaching of more than one subject with others as an integrated model. With the load of heavy curriculum expectations and administrative engagements, the possibility of teaching science comprehension strategies becomes a challenging task for the learners and the teachers of elementary grades. Grade six students who need strong training for comprehension will not find one period of science as enough time to learn science specific comprehension strategies, when considering the importance of practical use in ensuring they grasp the concept. As a result of this reality, the comprehension skill building for the language program becomes a background source for science comprehension (cf. Best et al. 2005; Chambliss and Calfee 1989). For the textbook authors, the challenge of publishing textbooks within the calculated limits of size, budget, and other demands poses the question whether all those demands can be fulfilled in one coherent format. With the escalating use of computer-based networks, textbook publishing trends also provide some specially designed web links to supplement hardcopy textbooks, or other additional resources. For example, Pearson Canada provides the following web link for textbooks with limited access, as the access is also conditional to the purchasing of the textbook:

http://www.pearsoned.ca/school/literacyinaction/literacyinaction4to6/crosscurricular.html.

Another example is Nelson Canada which provides the following link for open access:

http://school.nelson.com/elementary/science/bcscienceprobe/0176283102/studweblinks.html

The web link provided by Nelson Canada on the topic of electricity starts with "electricity comes from the movement of electrons" and on the following web pages it shows the flow of electrons with the help of a circuit. The focus of the current study is not to compare grade six students learning from the textbooks and websites, which could be a question of interest for future research studies in this field. The question arises whether grade six students can learn from the electron-related explanation of electricity or not. With the use of hardcopy contents of electron flow instead of web links, the experimental group observed in this comparison has shown effectiveness of the use of such models within the limits of this study on the textbook CT. The way with which computer technology and the internet can possibly affect the textbook industry has been argued by many scholars (cf. Wallis and Steptoe 2006; Walpole 1998). A report on the use of textbooks and technology (Rushowy, 2009) published in the Toronto Star on April, 29, 2009 (pg. A1 and A8) highlights some key points:

(1) As students' social lives are electronic, school life cannot only be based on paper and pencil. This can create a barrier among the learners, educators.

(2) With the rapid advances in technology, in a few years, it will be economical to give each student a computer rather than to constantly update textbooks.

(3) The current generation of students at school has seen computers from their early age, so it is an integral part of their lives. It is hard for this generation to imagine a world without fast and easy access to information.

(4) If students find the gap between the outside world and the classroom world in terms of lack of technological transformation of learning they have to go through an adjustment process. According to Rushowy (2009: A1) "Many students feel that when they come into school they have to 'power down' to fit into an environment that offers fewer options for learning than are available in the life they live outside of the school. This can erode students' perception of the relevance of education as they experience it in many schools today."

(5) The report claims a significant link between the learning environment and students' disengagement or engagement. The higher-level use of technology can also promote students' interest in learning.

(6) Despite the indication of students' interest in learning through technology, the report stresses that it is not necessarily about what new technologies we have available in our classrooms, but rather how we use them to teach various topics.

(7) Teachers also need training to use the technology in an effective way. Technology can lead to an inversion where young students and new teachers may have more information than veteran teachers.

Technological advancement will continue to impact textbook designing in many ways (cf. Caswell and Bielaczyc 2001; Hartley 2004). If textbooks published twenty years ago are compared with the textbooks published in the last few years, a remarkable change is observed as publishers themselves provide specially designed web pages to support their textbook contents (cf. Hill et al. 1981; Flanagan et al. 1983; Galbraith, 1999). The report published in the Toronto Star also notes that just the presence of technologies cannot be sufficient unless those technological tools are not used properly. In the context of this study on the textbook CT, it must be noted that if teachers are not pedagogically trained to effectively include profound understanding and reasoning of scientific concepts, the web-based learning may not address the conceptual needs. The previous studies show links between student interest and effective concept formation (cf. Wellington 2001; Hartley 2004). Nonetheless, the use of technology has to be applied with caution to keep a balance between using tools to promote student interest and developing necessary strategies to facilitate concepts.

2.15. Textbook analysis for interdisciplinary extensions

According to Knain (2001: 328):

> Teaching science in a cultural or social constructivist perspective offers students the opportunity to develop both critical abilities and an autonomous trust in science.

Science textbooks also need to be analyzed in terms of their capability to facilitate interdisciplinary focus. Many science textbooks have recently incorporated the strand of the environment in some topics, particularly with energy and electricity. The shift is increasing an interdisciplinary focus towards a greater use of technology. According to Wallis and Steptoe (2006:34), “kids need to learn how to leap across disciplines because that is how breakthroughs now come about. It’s interdisciplinary combinations- design and technology, mathematics and art—that produce *youtube* and *myspace*.”

The textbook CT analyzed, shows interdisciplinary links of electricity with the environment and the everyday use of some electrical appliances. Some links with linguistics include writing a cinquain poem on the use of electricity (the textbooks has shown some pictures to write about), writing assignments and oral communication. The textbook PT shows lack of such interdisciplinary components. That textbook includes highly structures questions at the end of chapters, many of them with a "right or wrong" or "fill in the blank" type questions. Some questions just need a short descriptive answer. Extensions to other domains is not included for the chapter analyzed on "electricity".

As discussed previously, curriculum expectations make an outline for the textbook designers and the educators to work within a certain framework, and within a given time limit. According to local and international demands the ongoing update in the curriculum is important in the computer-age world. The economic constraints and policy factors can hamper the process of ongoing updates in many parts of the world. Wallis and Steptoe (2006:36) remarks:

> The U.S. curriculum needs to become more like that of Singapore, Belgium and Sweden, whose students outperform American students on math and science tests. Classes in those countries dwell on key concepts that are taught in depth and in careful sequence, as opposed to a succession of forgettable details so often served in U.S. classrooms. Textbooks and tests support this approach. "Countries from Germany to Singapore have extremely small textbooks that focus on the most powerful and generative ideas," says Roy Pea, co-director of the Stanford Center for Innovations in Learning. These might be the key theorems in math, the laws of thermodynamics in science or the relationship between supply and demand in economics. America's bloated textbooks, by contrast, tend to gallop through a mind-numbing stream of topics and subtopics in an attempt to address a vast range of state standards.

There is a growing need to analyze Canadian and Pakistan's textbooks and curriculum outlines in light of the above conclusions. Roth et al. (2005) from the University of Victoria, Canada, have conducted research on science textbooks, particularly from the perspective of the use of pictures, and other icons. Roth (2005:260) suggests:

> A corollary of our suggestion would be a necessary reduction in the number of concepts that could be treated by textbook authors if the length of textbooks remained constant. The frequently dictionary—like treatment of scientific terminology would retreat in favour of more integrated discourse and inscription practices that are common in scientific communities.

The Ontario science curriculum (1998) revolves around the curriculum expectations, and as a result, textbooks tend to include information on those specified topics. This practise increases the range of topics, while the profound understanding needs more emphasis on fewer topics, as concluded by Wallis and Steptoe (2006). Overall, there is a growing need to analyze the elementary-level textbooks and curriculum (multiple aspects using mixed-method analysis), especially for science.

Some analysis of textbook design using "elements" and "linkages," as well as curriculum comparison with the textbook, is given in other sections of this work (under subheading 5.3.1). The main focus of those comparisons is not on interdisciplinary components incorporated in the textbook. There is however a need to expand the use of interdisciplinary contents with a wider range of domains to train students for making meaningful connections. Although the current research has a more specific focus to analyze one textbook, there are some extended parameters to explore a range of factors, particularly interdisciplinary factors in the textbook in the future studies. For example, Phillips (2006) has analyzed textbooks on the nature of science.

The comparison of one textbook in relation to the provincial-level curriculum highlights multiple links between the education policy of Ontario and the designing of the textbook. The use of explanatory text can be experimented on a wider range of textbooks. The methods for analyzing textbooks can be established further for consistency and accuracy based on theory and research paradigms. If the textbook analysis data is collected only from one dimension (either text analysis or learners' responses) it is difficult to compare the effectiveness in the learning process. If the textbook analysis data is collected from two dimensions —the students learning indicators and the text document by itself— there is a better chance to make more evidence-based comparisons. Some previous studies on textbooks have only focussed on data collection from three main domains: book reviews, students' perspective, and document analysis. To answer the question of the textbook effectiveness, there is more scientific evidence if data contains information on the text analysis and the students' performance.

2.16. Textbook designing process from the publishers' perspective

According to the publishers of the book CT, there are components that are generally followed in textbook designing and publishing: curriculum, students, teachers, context, and the process. Curriculum analysis is conducted to find the links between pedagogy and curriculum, distinction between the new and old versions, contents maintained, deleted items, and incorporating teacher opinion. The next factor considers how the curriculum could be well served by a resource, inquiry, labs, or content. The student success is incorporated by looking at what they are successful with and what they struggle with. The current learning skills of students are considered to include that factor in textbook writing. The age of students provides a guiding goal to include what activities they would like and what they would not like. The pedagogical and social factor of learning as individuals, in pairs and in groups is also valued in designing the proportion of tasks in the textbooks. The publishers also involve teachers in the content collection and writing tasks. The first factor is how teachers interpret the curriculum. In this case this question revolves around the teachers who would interpret the elementary science curriculum of Ontario. The teacher feedback focuses on understanding what has worked in the past, what they want to see changed, and their expectations for the resources. In terms of style, a publisher is concerned with how teachers would like to see it in terms of physical format. In terms of didactics, the publisher needs to know where the teacher stands pedagogically, whether they like a lot of labs for the students, what kinds of labs (quick labs, demo labs), and how these labs can best be included per unit workload. The context itself plays an important role in this discussion. The publisher considers if this title will be submitted to a review body, such as Trillium. As this field is very competitive, the publishers consider what type of market a particular textbook is going to face. School budgets allocated for using that textbook plays a role in this process. Knowing a Figure around the expected cost gives some parameters for investment. The current research in a given field of activity helps to upgrade that content area. The context also involves the users (administrators, parents, students, others) that will have an impact on the resource or expectations. The process of textbook background information collection, writing, and publishing takes about 24-28 months (Cobham 2009). Generally, questionnaires are sent to schools and consultants to ask their input, and one-on-one meetings with educators take place. These processes are further reinforced by focus groups that convene to get input on the textbook. Lead educators are identified, who have an expertise in the area. Often these people will be recruited to become involved as authors, reviewers, advisors. The resources are generally written by teachers, with the support of professional editors. The table of contents, unit outlines, materials, and prototypes are drafted. They are then reviewed by teachers and those identified as being able to help the development process. Resources are written, edited, reviewed, re-written, edited, designed, reviewed, edited, and finally published.

2.16.1. Delivered curriculum and the perspective of teachers on the textbook

The cycle of theory, research, and practice is at the centre of the learning and teaching process using textbooks or other similar interactions. As Moore (2006:43) remarks, “real curriculum is actually what is taught and this is often what is in the textbook -the text becomes the program-, not the course of study.” This notion has enhanced value when many frontline teachers in the schools under discussion have not taken any qualifications in science education (cf. Rowell and Ebbers 2004; Moore 2006).

Although the conceptual analysis of teachers is not the focus of this study, some feedback is given that can be useful for further research. Some teachers who have used the textbook that is analyzed for this study reported that they use only selected parts of this textbook, particularly the topic on “renewable energy resources.” The emphasis of teaching electricity revolves around the electrical instruments and everyday use, while the concept of electricity is not clearly addressed in the lessons. Some teachers reported that they find challenges attached with the sequence, design and linkages of the textbook. For example some of them preferred to teach static electricity before other experiments. They want to relate static charge to teach the concept of current. Teachers found the concept of atoms was missing to elaborate the explanation of electron flow. As a result, many teachers had to bring information on this topic on their own. Some teacher feedback also extended this conceptual gap with the lack of explanation for why some materials are conductors while others are insulators.

Based on the critique of some teachers who participated in this study, the textbook is limited in discussing electricity as simply being about the attraction of protons and electrons, requiring the teacher to bring to students the useful knowledge of why certain static current characteristics are observed with human hairs and not on metals. While teachers point to some lack of explanation in the textbook, the need for teacher conceptual analysis is a crucial topic in future research studies in Canada. Considering the needs of learners, education policy issues, cognitive factors, and making it more inclusive are integral components of the process for analysis and implementation. Among the teachers' own ways of using analogy to teach the concept of electron flow, some of them have used a ball, which different students throw to each other. One teacher summarized it as seeing more "why," rather than "what" in the textual information presented. This approach is the centre of scientific reasoning, in contrast to other aspects of learning about electricity that give simple details, such as the environmental and social factors of using electricity. One teacher reports, some types of electrical switches shown in the textbook are not familiar to the students' everyday experiences. Another aspect is that constant updating is needed to incorporate new inventions and ideas, such as the global interest growing in tidal energy and other newly developed sources of energy generation. As discussed before, many teachers who were approached appear to join the challenge of teaching elementary science, but do not have formal qualifications in this field. As a result, their knowledge of the nature of science was not clearly understood or implemented by many of them who have used this textbook. Some educators would even question how far we can teach grade six students on the themes of the nature of science. Some teachers reported to include science, technology, society, science as a body of knowledge, and science as a way of thinking in their teaching without having a profound understanding of the research trends for applying the nature of science. This feedback of teachers is also reflected in the statement of Moore (2006: 43):

> Teachers teaching themselves science generally should be suspect. Not only is there the lacking of formal education on which to build knowledge, but elementary teachers often find science activities and implement them without knowledge of science principles underlying the results of the activity.

2.17. Pedagogical links and HPS domain for atom related representation in the textbooks and students' responses

The development of science ideas has a long history, while the science concepts commonly discussed in the school textbooks have very limited representation of such ideas (Justi and Gilbert 2000). The current research trends with focus on the nature of science (NOS) also emphasize on this perspective of science education (Allchin 1995; Monk and Osborne 1997). According to Justi and Gilbert (2000:993), "it is suggested that the contribution of history and philosophy of science (HPS) to science education can be enhanced through a consideration of scientific models which are relevant to major sectors of the curriculum." The history of science can also reinforce the changing nature of science when students learn the patterns of the development of ideas in the theories of science, as explained in favour of using the "knowledge forum" model by Caswell and Bielaczyc (2001). The HPS integration model in the science textbooks and through other ways also has a pedagogical factor for students in which they learn how scientists accomplish a process of achievement and what shifts take place between the accepted concept of today and the modified concept of tomorrow.

Cognitive science has a prime focus on the representation of mental models (Johnson-Laird 1983). The research, theory, and practice on mental models and modelling have many unanswered questions to deal with. The role of model and modelling needs more specific parameters and robust terminology (Justi and Gilbert 2000). The challenge for understanding mental models is embedded in the fact that they cannot be directly evaluated, and they are mainly inferred through various modes of human communication, such as oral, visual, and written work, or expressed models (Gilbert and Boulter 1995; Justi and Gilbert 2000). Mental models placed in public domain become expressed models when they gain social acceptance. Along with the testing of the community of scientists they are called "scientific models" (Justi and Gilbert 2000; Gilbert and Boulter 1995). Those scientific models can also be called "consensus models." A scientific model designed in a given context, but altered with new inventions in science is also termed as a "historical model" (cf. Nersessian 1992; Justi and Gilbert 2000; Gentner and Stevens 1983). Justi and Gilbert (2000:994) assert:

> A historical model is not therefore necessarily a model developed by an individual or a small group of scientists, although this is apparently often the case nor is its development and use situated within a specific time period. The key issue is that it achieved consensus status within a particular context. A curricular model is a simplified version of any consensus or historical model, which is included in the science curriculum at any level of the education system.

The elementary level science textbook has a closer link to the historical model, as it provides a foundation for science education. On the other hand, research or university-level research work at the edge of making new discoveries has more emphasis on the consensus model. The designing and presentation of model-based strategy to HPS needs some way to characterize the historical models (cf. Lakatos 1970; Justi and Gilbert 2000). The historical model and the curriculum model of an atom have their roots in HPS, curriculum designing, curriculum delivery, and ongoing research on student performance using those models.

There are six models of an atom which are relevant in the context of textbook analysis: the ancient Greek model, the Dalton model, Thomson's 'embedded mass' model, Rutherford's nuclear model, Bohr's model, and the quantum model (Justi and Gilbert 2000). The earliest model of an atom as presented by the Greek philosophers had two distinct features: matter is composed of tiny indivisible corpuscles, and they are extremely hard and differ in form and position. Perhaps Leukippos was the first to coin the term atoms (March 2006; Justi and Gilbert 2000). The Greek model of an atom had long influenced many scientists and even up until the seventh and eighth centuries they were referring to this model. According to Partington (1939), Descartes thought matter was infinitely divisible. The ancient Greek model of an atom had no ground to explain the distinction between various types of atoms. Dalton attempted to explain this by indicating to differing physical weights of tiny particles (Nye 1976). Dalton's model did not include the forces between atoms, and were therefore assumed to be stationary (March 2006). J. J. Thomson showed the existence of negative charges by way of his experiments. This led to the further modifications of the atomic model. Geiger and Marsden experimented with the scattering of alpha particles, and there were some unexplained reasons for the behaviour of waves. The questions raised with this discovery opened doors for a new model which is called Rutherford's model. This model used the concept of nucleus and electrons, and described the very small ratio between the nucleus and the surrounding electrons. This model partly explained the exceptions raised by the experiment of Geiger and Marsden. The next shift of understanding atoms was explained by Bohr's orbit model, which used the quantization model. This model made some progress to show the internal structure of electrons. The Schrondinger equation dealing with dual wave nature and particle nature of light made a major change from previous models.

There are many other details attached to the development of the atomic model that are not discussed here in the context of textbook designing and classroom presentation. The didactic and HPS research leads us to consider that the importance of a model is a representative of the reality and not the reality itself, so it is not a copy of the system (cf. Justi and Gilbert 2000; Nersessian 1992). How do school curricula include HPS models in elementary level science? According to Justi and Gilbert (2000:998) "school curricula do not refer clearly to historical models." This notion is based on their study of nine science textbooks from Brazil and three from the United Kingdom by applying the description of historical models of the atom. Their study also finds a failure to discuss the relationship between theory and model. As Justi and Gilbert (2000:1001) note:

> The theoretical background on which each model is based is generally not clearly discussed in the textbooks analysed. They all give names and dates and sometimes describe experiments that resulted in discoveries that lead to the development of a given model. However, on many occasions this is disconnected information since the experiments are not related to the attributes of the previous model in the historical sequence.

For the province of Ontario it is concluded that from grade one to eight, students have almost no emphasis in curriculum expectations to learn about atomic models. A large-scale study is needed to analyze the curriculum direction, textbook analysis, and classroom processes on the study of atomic models in the Canadian education system.

2.18. The current study in relation to the previous studies

In a textbook study Lee (2007:31) concludes:

> In spite of the fact that high school science textbooks have played an important role in science education for over the past many years, textbook research is comparatively small compared to most of the research conducted in science education. Meanwhile, relatively many more studies have been conducted at the high school level in comparison to elementary school level and middle levels.

The review of previous studies on textbooks (within the research framework of the current study) show various shortcomings found in the language of textbooks, conceptual difficulties, complexities of science terms used, pattern of textbook designs, and many challenges at the pedagogical and administrative levels. There is the need to compare a textbook from various dimensions, such as, the occurrence of specific words in text and students writing, feedback on student learning from that book, and the analysis of the textbook on the use of explanatory sentences. Perhaps this textbook analysis of CT and PT will encompass some extended dimensions that are not included in the conventional studies. Data on textbook analysis is more stable if it comes from what is presented in the text and how students respond to it. The current study has a distinction of applying document analysis methods for specific needs (Figure 7). The document analysis includes comparing sentences, lexemes or keyword occurrence frequency, as well as paragraph analysis for some specific items. The current study also includes an experimental study in the classroom within the specific parameters of this study, provided some variables are not completely controllable due to individual differences and social factors. The data of this study provides some evidence from both domains of research procedures. Some aspects of the research in the previous studies are shown in Table 2, to give an overall review. It gives a brief description of those studies.

Table 2: Some dimensions of studies on textbooks[1]

No.	Year	Authors	Journal	Target Age Group/ Grades	Study Factors	Study Highlights	Future Implications
1	2003	Diakidoy; Kendeou; Ioannides	Contemporary Educational Psychology (28) 335-356	6th	Effects of text structure, concept of energy, using expository or a refutation text	Students used refutation text outperformed the other group. Refutation text facilitates understanding	More research is needed to explore extended effects of this process
2	2001	Hubisz	The Physics Teacher 39 304-309	6,7,8,9	Experts reviewed a number of textbooks	Two year search founds that the textbooks will not effect the desired change in the middle schools of USA	Use understandable vocabulary format and attractive illustrations. Use more activities that can be applied. Keep a balance. Quizzes based on reflecting students' understanding
3	2002	Peacock; Weedon	Research in Science and Technological Education 20 (2) 185-197	Year 5	Strategies that children use to read science text	Used observations, interviews with students, teachers and questionnaire. Students experience difficulties in understanding text and linking visuals to text. 'Literacy Hour'	Effective plan for text use in science and literacy lessons

[1] This is just a brief description and may not reflect complete information about the actual study. Details can be seen in the actual text

No.	Year	Authors	Journal	Target Age Group/ Grades	Study Factors	Study Highlights	Future Implications
						strategies not transferred during science lessons.	
4	1994	Driscoll; Moallem; Dick; Kirby	Contemporary Educational Psychology (19), 79-100	8th grade	Natural use of the textbook (science), observed a 3-week unit, used student questionnaire, student and teacher interviews, text check to see homework use	Textbook used mostly as a dictionary (may be due to emphasis on vocabulary learning). Textbook provided no instructional strategies.	Textbook has to play more effective role in knowledge construction. Design textbooks that are more than a handbook. Textbook provides extended links to other sources.
5	1999	Walpole	The Reading Teacher Vol. 52, No.4, 358-369	3rd, 4th	Designed a rubric to compare two editions of the textbook, review and Comments count of signal words, illustrations and more. Brief comparison of some parts of the text. Reflections and process of reading used by grade 3,4 students	Some changes wee found in he two textbooks (editions) compared. Structure of topics, illustrations, signal words etc. Different students used the text and illustrations differently for discussion	Changing text changes thinking. Change in instruction is also needed.

No.	Year	Authors	Journal	Target Age Group/ Grades	Study Factors	Study Highlights	Future Implications
6	2001	Wellington	School Science Review 82(300) 71-82	Elementary/ Middle	Historical developments shown with quotes, illustrations and arguments	Textbooks have changed during the last century (form and purpose). Analysis of various factors on the textbook	Text has to be more readable. Encourages active reading and use of variety of text resources. Emphasizes to teach students how to read in science.
7	1989	Chambliss; Calfee	Educational Psychologist 24(3) 307-322	4th	Analysis of textbooks from Japan, Singapore and U.S. Approach to textbook design based on cognitive psychology, comprehension research, curriculum theory. Identifying descriptive patterns (list, topical net, hierarchy, and matrix), sequential patterns linear string, causal chain and branching tree).	All three textbooks analyzed have strengths and limitations. The analysis shows some lacks in coherence. Gaps were found in text and concept domain.	Science textbooks have to be organized schematically rather than taxonomically, content organization according to coherent and explicit design. Link text and student knowledge, effective use of functional devices, use of better examples etc.

No.	Year	Authors	Journal	Target Age Group/ Grades	Study Factors	Study Highlights	Future Implications
8	2002	Newton; Newton; Blake; Brown;	Research in Science & Technological Education 20 (2) 227-240	7to 11 years	76 primary science textbooks analyzed using a schedule to find the occurrence of various types of classes. Explores concern for 'explanatory understanding' by the use of clauses that gives reasons.	Lack of concern for explanatory understanding. Less use of those clauses that deal with reasoning and explanation. One book showed some concern for explanatory understanding.	Science is not just acquisition of facts and descriptions. Emphasizes on explanatory understanding
9	1983	Cohen; Steinberg	Reading research Quarterly 19 86-101	4th, 5th, 6th	Finn's test, readability of intermediate grade science textbooks	Supports Finn's observation, analyzes transfer features of technical words	Technical terms are integral part of science so their numbers should not be reduced to improve readability. Subject area differences have to be considered in evaluating the reading difficulty of science text.
10	2006	Phillips, M	Dissertation , Faculty of Education, University of Houston	Grade, 6,7,8	Exploring the balance of 'nature of science' in the science textbooks	Uses Cohen's Kappa (k) and Krippendorff's alpha (a) , finds imbalanced presentation about the nature of science	Informs teachers to supplement students learning to fill the gaps about the 'nature of science

Chapter 3 METHODOLOGY

This chapter provides the details of research design, research questions, and the context of the research with a discussion from various perspectives. The details also include the rationale for the research processes, the validity of data, the details and reasoning behind the use of additional resources, the use of sentence analysis, paragraph analysis and lexical conceptual profile parameters. The limitations of the study are also discussed.

Theories of learning have close connection with the science education approaches and paradigms (cf. Glynn et al. 1991). Various learning theories have influenced science education ways and resources in the last few decades (cf. Glynn et al. 1991; Hartmann et al. 2002). Theories of learning with philosophical base, psychological base, social contexts have their own focus and changes have merged in the frameworks, in general those theories explain various dimensions of learning (cf. Hammond et al. 2001). On the other hand one theory which can explain every aspect of how we learn is a question for future research and multidisciplinary studies (cf. Geake 2009).

Textbooks designing and their use have many dimensions, for which many learning theories analyze them from various lenses. The textbook and its use also have a close relation to the work of Vygotsky. According to Vygotsky (1997:106) "every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as an interpsychological category, then within the child as an intrapsychological category." In this context, the outside environment with textbook, teacher and other learning factors interplay with the inner processing of students.

The current research on the textbook is comprised of experimental or empirical research, and document analysis which is applied in different frameworks. The analysis of the textbook is more comprehensive if the textbook content is analyzed, and also when students provide information by reading and reflecting their understanding in an experimental research environment. According to Luecht (2007: 337):

> Even the most sophisticated psychometric models cannot manufacture highly useful diagnostic information from a unidimensional test. The data itself must be multidimensional, and the extractable dimensional structure needs to hold up over time and contexts.

Although there is no specific research method for textbook analysis, a combination of methods has been used by various researchers (Chambliss and Calfee 1998). For example: counting the number of clauses to show concern for the explanatory sentences, readability tests, text design taxonomy, descriptive and sequential patterns, Krippendorffs alpha and Cohen's Kappa values, educators reflective reports, and others (Phillips 2006; Chambliss and Calfee 1998; Newton, L, Newton, D, Blake and Brown 2002; Garner 1987; Hubisz 2001; Johnsen 1993).

Readability formulas have some drawbacks. For example, a high degree of different results can be obtained from the same passage, or a lack of attention to the writing structure and conceptual details can occur (cf. Chambliss and Calfee 1998). In order to use this method on textbook analysis, an initial text design has to meet the word selection criterion. Due to these reasons this method of testing is not useful for the current study of a textbook on electricity.

Some studies on textbooks (or reports) are based on the critical comments of experts (Hubisz 2001). It is obvious that experts, educators, editors, curriculum designers can give critical information to reduce errors or add certain items for better quality of textbooks. There is a great value in knowing the perspective of experts (who are not students of that grade) to improve the quality of the textbook, however, in terms of a research procedure there has to be a more balanced way to justify the data or an individual's opinion. In some situations, teachers' feedback can also work as action research model for textbook analysis. According to Gay (1996:10) "the primary goal of action research is the solution of a given problem, not contribution to science." The current study has a wider scope than finding the solution to a local problem. However, the author of this research gives feedback in the discussion as observed by a frontline teacher.

Studies indicate that the strength and number of causal connection is interrelated with the chances of concept attainment and information recall (Newton et al. 2002; Britton and Graesser 1996; Chall and Conrad 1991). In order to explain a certain concept for a grade six level textbook (electricity), it is important to use related vocabulary. Therefore, the occurrence of certain keywords shows the concern of the textbook to explain a specific concept around that keyword(s). The occurrence of specific types of keywords is included in this study to explore the presence or absence of certain key indicators.

3.1. Research questions

The **research questions** for this study are:

1. To intend to explore the evidence of explanatory understanding in the two textbooks (from Canada and Pakistan) on the topic of electricity for Grade 6 students (based on the count of keywords, classification of sentences and other comparisons).

2. The second research question is intended to explore the evidence of certain key-words in the students' writing from the experimental and control group.

3. The third research question explores if the students in the experimental group

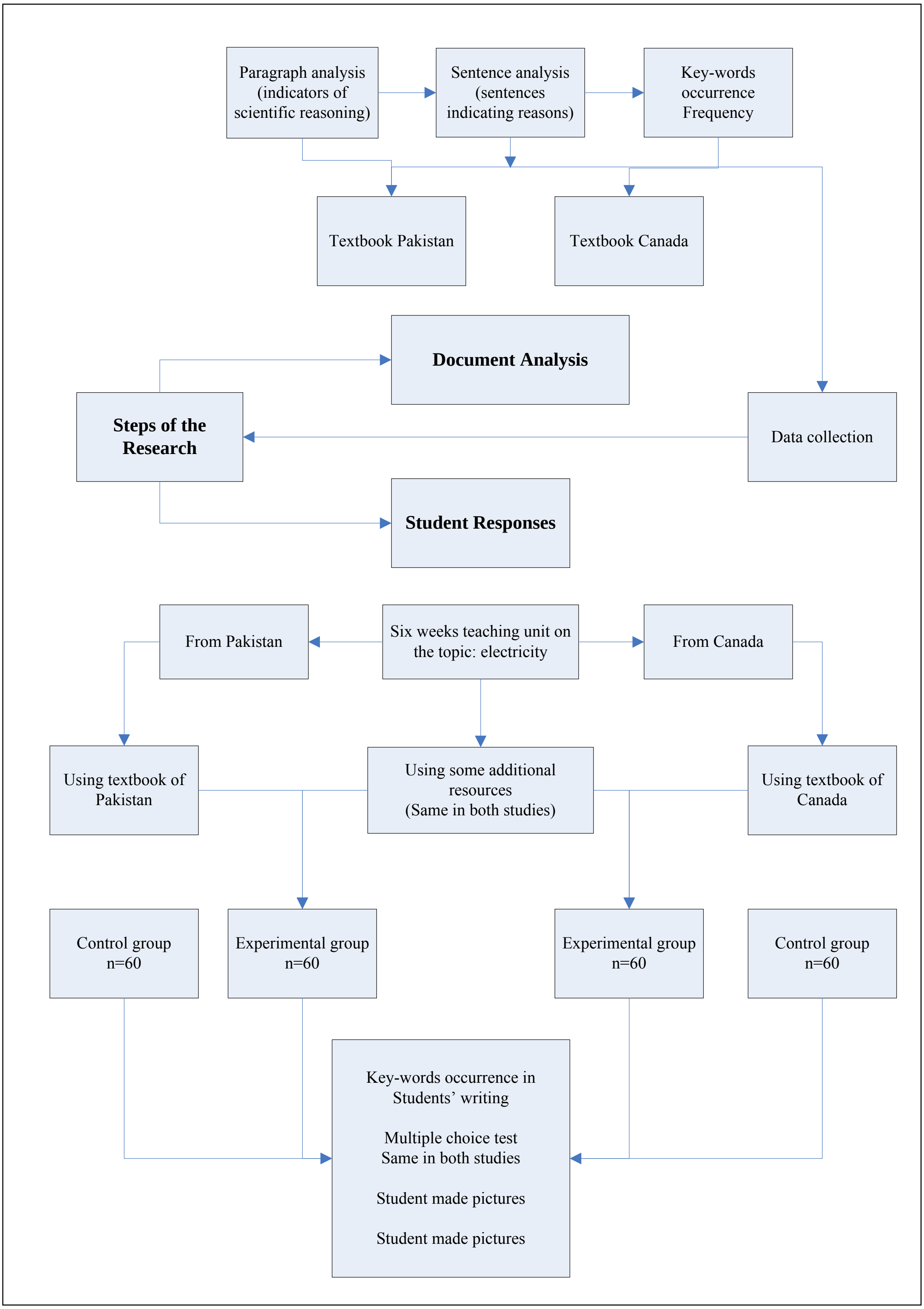
scored higher than the control group in the same multiple choice test when the students in the experimental group were given the opportunity to learn from the same textbook and some additional resources.

3.1.1. Research design

The multiple aspects of research design are elaborated using a graphic organizer (Figure 6).

Multi-method research is useful in such frameworks, where unidimensional test can not address the needs of research questions (cf. Luecht 2007). The research design for this study collects data from the two Grade 6 science textbooks on the topic of electricity. The data collection process is comprised of content analysis: counting the frequency occurrence of 25 key-words in both relevant textbooks, the comparison of sentences to explore the occurrence of reason based sentences, paragraph analysis for the evidence of explanatory descriptions. The data collection from students is based on research design with experimental and control group (for both studies in Pakistan and Canada). As quasi-experimental research design, according to Johnson and Christensen (2008:328) “does not provide full control of potential confounding variables. In most instances, the primary reason why full control is not achieved is because participants cannot be randomly assigned to group.” Cohen et al. (2005:214) distinguish the parameters of quasi- experimental design as having control over ‘the who and to whom of measurement’ and lack of control over ‘the when and to whom of exposure.’

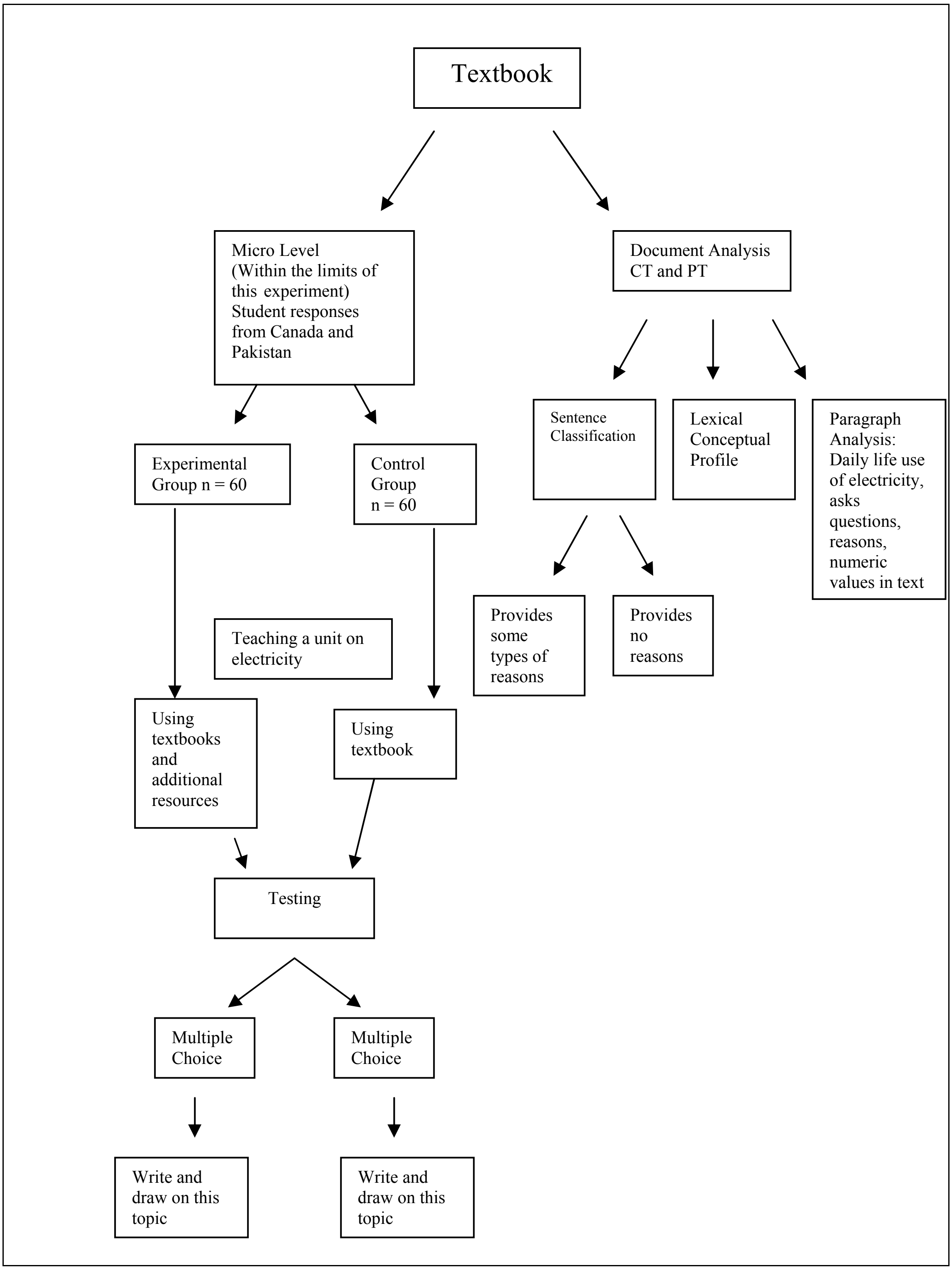
Figure 6: The research design



3.1.2. Research context

The Figure 7 shows the research context for the textbook analysis.

Figure 7: Textbook analysis



3.1.3. The context of study sample, students, teachers, learning resources

The selection of classes and choice of other factors in the school setting is sometime already given and the research is conducted in that situation.

The students sample was a mix of Grade six 240 students from various learning abilities distributed in four groups-classes and in two countries. The age group was almost eleven to twelve years in both countries. With 60 students in each group, there were students with various learning levels (lower, middle and higher level students) in each group with almost equal numbers of each learning level.

Class formation is conducted by the local system is which students' previous performance and teachers' recommendations are considered to form the new classes in the beginning of school year. In general, there is focus to put equal number of students of each learning level (lower, middle, higher) in a given grade, however there could be some slight variations in the total number of students in each class. The average class size was 20 to 25 in both countries.

The school was a multicultural, inner-city school in Toronto and the other one was an Urban School in Punjab, Pakistan. The majority of students were from middle to lower economic class. All students in Canada were fluent in English, although many of them also speak another language at home. The students in Pakistan although studied using English medium, however, the majority of Grade six students wrote the paragraphs using Urdu language. The student population in Canada included male and female students (experimental group, n=60, male=32, female=28, control group, n=60, male=29, female=31). The student population in Pakistan had only male students in each group (n=60, male=60). This is how the local school works in that part of the country. The students were from the schools that are government funded in both systems. Both schools were located in the urban area. Students in Canada included students from various cultural backgrounds. Students in Pakistan were from primarily the same cultural groups.

In both studies, the teachers were different in the control group and the experimental groups. In both studies, teachers were certified for their local teaching purposes, with almost over a decade experience of teaching to this group of students. The researcher also taught the experimental group in Canada. For all other classes, researcher only provided the resources and did not involve in the teaching process. This aspect of research design shows higher external validity as other teachers in Pakistan also taught to observe the variables in the learning process.

The length of teaching unit was same: six weeks. The control group (or comparison group) received regular teaching methods and resources by a regular grade six teacher (such as using the textbook for reading and doing exercises, activities, experiments, and discussions). Conversely, students in the experimental group received the same teaching methods and resources by a regular teacher and additionally, also extensively used dictionaries, encyclopedias, and books with information on electricity (details of additional resources is given under subheading 3.7 and 3.7.1). The multiple choice tests and the students' writing tasks were conducted in the last two days of the six week teaching unit on the topic of electricity.

The 25 keywords frequency occurrence compared were the same for the two textbooks (electricity), the control group of both studies, and the experimental group of both studies. With the analysis of same 25 keywords in the two textbooks and the two studies of students, comprised of experimental and control groups, along with comparing all research frameworks, the results indicate the ability to infer a causal relationship exists between two variables (based on the parameters explain by Cohen et al. 2005; Johnson and Christensen 2008). Those are some indicators of internal validity in a quasi-experimental design. The repeatability of the results also refers to the experimental reliability of the research design (cf. Johnson and Christensen 2008)

To compare if there is a threat to validity or not, one can argue what if the students would have studied some thing outside the classroom using internet which would have altered the results. If this would be the case with the control group their results would show improvement compared to the experimental group. The result does not support this as the students in the control group still performed lower than the experimental group in both countries. So even if one can hypothesize students may have used some other resources this would not bring a significant difference in the results in the given parameters of the study. The teachers also discussed on daily basis during the unit what students are learning about the given topic. No student reported or indicated by their work in any group to have been using such additional resources outside the classroom.

3.1.4. The dimensions of multiple choice test

The study in both countries and in both groups of experimental and control group included an aspect of quantitative analysis with a use of multiple choice test. The multiple choice test had 19 items. Out of which 4 questions were based on selecting one correct answer from four possible answers and 15 questions were based on selecting a true or false statement (Appendix 1). The selection of multiple choice questions has a focus on the links between electricity and electrons. This technique was applied to have a better possibility of presenting conceptual variations with a range of answers. On one side this technique provides quantitative framework of data and on the other side the researcher can compare this aspect with other frameworks of data collected from student responses. The data obtained is also presented with statistical dimensions such as t-test and mean. The use of various frameworks is an attempt to improve the reliability of data.

3.1.5. The dimensions of study validity

The question of validity is further addressed by the following critical comparison. If the students have given responses to the multiple choice tests (same test in both studies for the experimental and control group) and one can argue about students may have guessed the correct answer. The data collection process had other dimensions to avoid a single indictor for student performance. A different way of reflecting student responses was through their own writing on this topic and comparing the occurrence of keywords in their writing. The result is not just based on the multiple choice tests. This process is applied to enhance the validity of the research design. If the student responses show higher performance of the experimental group as compared to the control group, then it can not just be attributed to the student guesses of correct answers for the multiple choice test. If the students in the control group in both studies show lower score in the multiple choice test, there will be some evidence to argue why the scores were increased in the experimental group when textbook use was augmented with the same additional resources in both countries (the list of additional resources can be seen under the sub-heading 3.7, which also shows consistency in the use of additional resources). One aspect of the additional resources was they provided atom and electron related explanation using pictures about the concept of electricity, some thing which was either missing in the textbook compared (Canada textbook analyzed) or it was given with lack of clarity with a few sentences and no pictures was given to link electricity and electrons (Pakistan textbook analyzed). The learning resources, including additional resources were available in the classrooms for both studies. This information and the background work also promote the validity of the study. Gay (1996:342) asserts:

> Experimental research is the only type of research that can truly test hypotheses concerning cause-and-effect relationships. It represents the most valid approach to the solution of educational problems, both practical and theoretical, and to the advancement of education as a science.

The flexibility of experimental research method allows the manipulation of an independent variable, while this is not the case with causal comparative research method (Fraenkel and Wallen 1993). According to Donovan and Smolkin (2001:438) "there is a need for experimental research that examines which methods of working with in-service teachers on texts in science instruction will produce the greatest changes in practices and attitudes." In view of this fact, the experimental approach was considered more relevant for this research study. There are, however, certain limitations in using this method of analysis. This research study includes a research design with various frameworks discussed under the subheadings. White and Gunstone (1992:3) remark:

> If you want to know the meaning of a word like *democracy* or *energy*, you can go to a dictionary for a definition of it, but that definition alone is hardly likely to be sufficient for you to feel that you understand the term to any substantial degree. For understanding, you would want to know more about it. That is, to understand a concept you must have in your memory some information about it.

Based on this fact students in the experimental group were also exposed to finding information from the encyclopedia and other resource books with an opportunity to discus them. The effect of this contrasting factor can be compared in the multiple choice test results and student writing and pictures. This comparison will also show if a textbook can work better in the comparable conditions when more resources are supplemented. Based on the findings of science textbook analysis, Phillips (2006:vii) suggests:

> Given the impact of textbooks on learning, it is recommended that teachers be informed of the shortcomings of these texts to enable them to supplement content where it is lacking.

As the focus of this study is not about concept formation processes and their development, a brief conclusion in this regard is given by Keil and Wilson (2000: 280) "an explanatory framework shows how the phenomenon to be explained follows from the framework, typically in a causal manner." Extending the pattern to give reasons, an interesting connection is to see how electrons can be caused to make electricity, this might give some form of causal explanation according to the age of students. It is noteworthy to see Keil and Wilson (2000:289) conclude:

> Our overall analysis suggests that children's explanation for the physical world show the same essential structure as those used by scientists, except that scientists include a requirement that explanations be potentially testable.

This study is in fact not intended to compare the understanding of the general public versus that of scientists. On the other hand, student performance in the experimental and control groups show some details of the students' explanation and understanding of the same idea.

The survey method involves asking questions to a large group of population about a specific issue (Fraenkel and Wallen 1993). The practical manipulation of an environment in which already existing opinions can be contrasted with another variable of particular interest is not possible with the survey method, especially for this age group and textbook comparison. Experimental research method works with a limited sample, and therefore, all conclusions are not easily generalized for all places and broadly varying learning conditions. There are obvious "population validity" and "ecological validity" concerns for various compositions of samples (Gay 1996:346). There are personality traits of the experimenter, such as, gender, culture, age, and anxiety level. Rosenthal 1966 refers to all these factors as 'experimenter personal-attributes effect' (cf. Gay 1996:354). In this textbook analysis, the limitation of this study is also due to the fact that it is only tested in a specific school setting, as well as if students were getting any outside influence at home that might have slightly altered students learning (although reasonable effort was made to minimize this effect, such as avoiding to watch a TV program or visit websites with information on electricity during the period of this study). The impact of such individual effect may not have sharply altered results for various testing tasks. The use of various frameworks is an attempt to eliminate unforeseen influencing factors to some extent. However, this research is limited to this specific textbook and learning setting applied for this testing. As Cohen et al. (2005) conclude the quasi-experimental research design provides the parameters to accomplish a study with certain variations.

3.2. Document analysis

The visual and written data in any newspaper, textbook, novels, or advertisements is analyzed through this method. This process sometimes reveals and reconnects conscious and unconscious beliefs and ideas given in a document. In order to make a fair comparison, the researcher has to select and analyze specific aspects of the document in some form of measurable categories. According to Fraenkel and Wallen (1993:390):

> This is the nub of document analysis – defining as precisely as possible those aspects of a document's contents that the researcher wants to investigate and then formulating relevant categories that are so explicit that another researcher who uses them to examine the same material would find essentially the same proportion of topics emphasized or ignored.

Although textbook study does not have a specific method of analysis, however, the research parameters, categories and content comparison requires the same formulation for the study. Information or conceptual resources that may not be easy to extract by direct observation or other similar methods can be obtained by the researcher without involving or interacting with the authors of the textbook (Fraenkel and Wallen 1993). Due to multidisciplinary nature of textbook analysis, many aspects of textbook analysis interest researchers; for example, types of sentences used, key-word occurrence, corpus related comparisons, language and the level of various target learners, use of various types of pictures, balance in the choice and presentation of topics, readability tests, students' responses on learning from a textbook, teachers' responses on teaching from a textbook, administrators' perspectives, cross cultural studies, historical changes (Phillips 2006; Wellington 2001; Cohen and Steinberg 1983; Johnsen 1993; Chambliss and Calfee 1998; Newton, Newton, Blake, and Brown 2002). Korfiatis , Stamou, and Paraskevopoulos (2003:74) describe content analysis as:

> Content analysis constitutes a research technique for the systematic and quantitative description not only of content, but also of formal characteristics of messages. Content analysis is applied to all sorts of communication (verbal, visual etc.) and is not confined to documentary research (texts), but is also extensively used for the analysis of open questions of questionnaires and interviews. The systematic coding of messages is made by means of the construction of categories. Thus, content analysis involves the transformation of data into categories, which express the research questions of each study.

Berelson (1952:18) defines content analysis as "a research technique for the objective, systematic, and quantitative description of the manifest content communication." Content analysis is also considered as a method of observation, where instead of observing people's behaviour in a direct mode, such as interviews and responses to questions, the researcher takes the communication made by the people and asks questions of the communication modes, and traces the varying similarities and differences (cf. Lee 2007; Holsti 1969). The multipurpose nature of content analysis is also discussed by some scholars. Holsti (1969:2) describes this process as a way "for investigating any problem in which the content of communication serves as the basis of inference." According to Fraenkel and Wallen (1993:548) document or content analysis is "the process of inductively establishing a categorical system for organizing open-ended information." Weber (1990:9) discussed content analysis procedure as "a research method that uses a set of procedures to make valid inferences from text." The above discussion shows a variety of ways in which researchers have identified the content analysis procedures. While the descriptions vary, the core idea of classifying a text or other modes of communication using certain codes remains the same. Lee (2007:20) concludes that "despite the diversity in content analysis, researchers agreed that content analysis is a scientific research technique per the descriptions of features of content analysis."

The current research trends apply content analysis for a variety of purposes (cf. McComas 2008; Fraenkel and Wallen 1993), especially due to the technological facilities available to categorize, codify and classify text or other types of data. This rationale provides supporting grounds for conducting textbook analysis to find the frequency of certain lexemes which can identify the presence of certain elements in the text design. The same lexemes can also be compared with the students' writing samples to make further comparisons within the parameters of this study.

3.3. Picture count

The use of pictures in the textbook is a multidisciplinary topic that can be debated from various perspectives, such as psychology, education, art, computer graphics, science, sociology and other subjects. Textbook picture analysis is not the focus of this study; however three types of pictures are counted to show some general integration of text and pictures in this textbook. Pictures also work as subheadings (Mandl and Levine 1989); therefore this study only shows the number of pictures included in this textbook in terms of camera/computer graphics, including hand made pictures, circuit diagrams, and charts.

3.4. Sentence classifications

Explanatory understanding is considered a valued goal in science education, although in many cases it is not necessarily a major focus for elementary school teachers

(Newton et al. 2002). In general, understanding has three important functions: connecting information pieces, connecting unknown with known information, and constructing knowledge with integration (Nickerson 1985). In some textbooks, we can notice many sentences that contribute to the general observation of the phenomenon or scientific process. However, the actual scientific reason is missing in the text. This type of text may not be very useful to facilitate explanatory understanding. According to Keil and Wilson (2000:280):

> It seems to us that placing a phenomenon in some larger conceptual framework is the conceptual core of people's everyday use of explanation. For example, suppose someone asks, 'why did this balloon expand when placed in the sun?' Statements that do not place the phenomenon in a larger conceptual framework, such as 'I saw it get bigger' or 'I like balloons,' simply do not constitute explanations, whereas statements such as 'it contains a gas, and gases expand when they are heated' or 'the gas in the balloon is composed of molecules, and they strike harder against the sides of the balloon when they are heated' are canonical examples of explanations.

The extensive use of explanatory sentences gives some indication of showing concern for explanatory understanding in a textbook (Newton et al. 2002; Keil and Wilson 2000). Children need training to construct a reason oriented culture of understanding —instead of just collecting facts— in order to facilitate their understanding of science. The question is how we can observe the presence of explanatory sentences in a textbook. Newton et al. (2002) have established a schedule to find the presence of various types of clauses used in the textbook. That schedule has the following clauses: aim, condition, consequence, explanation, purpose, prediction, direct attention, irrelevant, and not classifiable. According to the schedule designed by Newton et al. (2002), if a clause is classifiable in more than one category, the priority will be given to this order: explanation, purpose, condition, consequence, not classifiable and irrelevant. According to Newton et al. (2002), if a clause is about a prediction or the directing of attention, all clauses of aim will be marked A, label the first or only clause of a prediction as a prediction, label the first or only clause of a directing attention as direct attention. If a prediction or direct attention hides a clause of explanation, the titles "purpose," "condition," or "consequence" have to be added in brackets. The advantage of this classification is the breakdown of a variety of clauses. From a psychological perspective, the final conceptual outcome of a sentence may alter in some way, depending on the combination of two clauses in a sentence. If multiple-clause data (as discussed above) is only seen in the final graphs of the research report, it may not be easy to figure out the overlap patterns of classifications. As indicated above, Fraenkel and Wallen (1993) suggest for document analysis procedures, there has to be consistency in the classification patterns so that other researchers also find same pattern of classification (presence of hard evidence). In view of this rationale, this textbook analysis avoids many categories of clauses. The other alternative is to classify full sentences in fewer but more distinguishable categories. For this reason, it classifies the textbook only in two main classes:

sentence that provide no reason and the sentences that provide a reason or reasons. This classification pattern is further supported by the rationale given by Newton et al. (2002:228):

> Science is not simply stamp collecting; it seeks reasons. Reasons in explanatory understanding are of three main kinds: causal (or mechanical), functional and intentional (Brewer et al. 2000; Leon and Penalba, 2002). The first supplies reasons in science like: 'the image is upside down *because light travels in straight lines and the rays cross at the pinhole.*' The second provides reasons like: '*We have a translucent screen opposite the pinhole so that you can see the image*.' The third supplies intentions such as: '*I made the pinhole camera because I want to figure out how it works.*'

Another common way of providing reasons among scientists is to relate to a mathematical format, or refer to a scientific law and develop a cause-and-effect connection logic. The "cause-and-effect" sentences provide some kind of reason as to why something happens, and includes sentences with "because" and "if." This classification system is in accordance with the sentence examples of Keil and Wilson (2000). This classification system gives hard evidence that can be verified in terms of how a particular sentence is classified. In view of the size and focus of this study, the researcher has used this system of classification as shown in Tables 4 and 5, and Appendix 3A.

Newton et al. (2002) discover larger numbers of clauses come under 'not classifiable,' and a very small number of clauses fall under other categories (e.g. prediction, explanation, consequence, condition). In other words, the clause occurrence pattern shows a very small number of clauses that provide reasons and explain a phenomenon, as well as a large number of clauses that are just declarative type sentences (or close forms of it). The textbook designing attempts to incorporate various factors and the presence of cause-and-effect sentences/clauses tend to get less attention in many cases. The lucrative textbook industry depends on the demand of the buyers. Perhaps our textbooks might include more explanatory sentences if publishers get this message from those who buy and use the science textbooks. On the other hand, a science textbook can not show concern for explanatory understanding without explaining scientific reasons where it is possible (White and Gunstone 1992; Newton et al. 2002; Keil and Wilson 2000). Although explanatory understanding needs explanatory sentences, the process of understanding has much wider conceptual links that go beyond to providing reason in a sentence (Britton, Woodward and Binkley 1993; White and Gunstone 1992; Keil and Wilson 2000).

Despite many interdisciplinary components of the textbook designing, a specific concern is to find the link between the topic and 'curriculum expectations' for the given subject. For example, can we claim that a grade six science textbook on electricity has shown concern for explanatory understanding while the actual explanation of the flow of electrons is not given to show the process of electricity? Sentence analysis can bring more information to probe this question.

Sentence classification from the syntactic point of view deals with declarative, interrogative, and imperative types (Steer and Carlisi 1998). This type of sentence classification can help to compare the perspective of grammar. The pedagogical value for a learner is difficult to evaluate from an explanatory dimension by exploring the frequency occurrence of the syntactic patterns of sentences. As Newton (2002:227) remarks:

> The terms 'description' and 'explanation' in general use tend to be used synonymously although they are, in reality, discrete processes (Brown and Wragg 1993). A description can be a rag-bag of facts—unconnected pieces of information. An explanation, on the other hand, relates the facts and ideas.

Due to this reason, the classification of sentences from a syntactic perspective is not included in this study.

3.4.1. Paragraph analysis

Fraenkel and Wallen (1993:390) asserts:

> A major advantage of document analysis is that it is unobtrusive. A researcher can "observe" without being observed, since the "contents" being analyzed are not influenced by the researcher's presence. Information that might be difficult or even impossible to obtain through direct observation or other means can be gained through analysis of textbooks and other available communication materials without the author or publisher being aware that it is being examined.

Paragraph analysis can be used in many ways in content analysis procedures, however one of the common uses in this field is observed in the comparison of the "balance of the themes of the nature of science" (Phillips 2006). In order to compare the balance of the themes of the nature of science in the textbooks four conceptual components are compared. According to Phillips (2006:50): "The themes of the nature of science include: (a) science as a body of knowledge; (b) science as a way of investigation; (c) science as a way of thinking; and (d) the interaction among science, technology, and society." The first theme is about the transmission of science facts and science subject matter. The second theme compares the methods used in the science topics. The third type relates to the general way of thinking used by scientists to discover various ideas. The fourth theme illustrates the interrelationship between science and society. From a critical perspective, the word "balance" itself needs specific parameters defined for those themes; how much of each theme can comprise a balance remains an arguable question. In order to compare the element(s) of indication for each theme, paragraphs are analyzed by various coders. What will constitute that balance among the four factors being analyzed for grade six level students? The rationale of the initial training of teachers for this method raises some questions on the prior influencing of experienced teachers working as coders. The statistical value of *kappa* is used to numerically compare the inter-topic relationship of indicators for all four themes. Some extended versions of content analysis are also used according to the nature of text (Fraenkel and Wallen 1993:390).

In a current study, one type of content analysis is applied on the sentences of the textbook. From a semantic point of view, some types of extended meanings are not reflected only in one sentence, but the meaning also needs a paragraph analysis to enhance the validity of the data. The use of numeric information with science text is emphasized by Lemke (1998, p. 90) in these words: ‘‘to do science, to talk science, to read and write science it is necessary to juggle and combine in canonical ways verbal discourse, mathematical expression, graphical-visual representation, and motor operations in the ‘natural’ world’’.

In order to conduct paragraph analysis, each selected paragraph is also analyzed from four dimensions: (1) discusses daily life use of electricity, electricity resources; (2) asks readers to “think about” or “ imagine,” asks questions, asks to identify, asks to compare; (3) explains something using reason(s); (4) includes numeric values (2 km, 1000 kWh, 1888 AD). The four categories attempt to compare the use of word electricity in daily life, divert attention of the reader to extend links with other broader fields, reasons provided, and the inclusion of numeric values in the text. This analysis provides a valuable comparison of the paragraphs given in the textbook. The analysis of paragraphs along with the analysis of sentences provides multiple data to support the validity of the figures. The process of categorization of sentences and paragraphs is documented in the appendices of this study to present the hard evidence.

3.5. Lexical-conceptual profile

In regards to discussing textbook design, Chambliss and Calfee (1998:18) remarks “a coherent design starts with a small set of distinctive elements, and uses linkages to mold the elements into a thematic whole.” Proper text designing has two important components: right elements and right linkages. The use of right words in relation to the topic is an important factor for the right design. Relevant words/terms are important to describe certain processes and events.

Lexical-conceptual profile refers to the collection of certain keywords that are found in a specific written document, such as a textbook or students’ writing. In order to compile an initial list of the keywords to make comparisons for a lexical-conceptual profile, commonly available student dictionaries, textbook glossary, and encyclopedias were consulted to see some frequently used words to describe the word electricity. A special emphasis was given to the keywords that are used to explain reasons rather than just describe common facts. For example, the specific use of the words *electrons* and *atoms* in relation to describing electricity, as compared to more commonly used keywords, which describe a general use of electricity such as *batteries* and *light*. In principle, the understanding of students can be reflected with or without using the keywords taught from the textbook. However, a more convincing fact about the impact of some keywords about electricity comes from the evidence of students' work. If students in the control group show less use of certain keywords and the students in the experimental group show more use of some keywords in their written work, there is some impact of those keywords in the students' learning. If those keywords (and pictures) reflect more explanatory work, perhaps more use of explanatory sentences (and other supportive resources involved) can be useful for the students in similar learning environment.

3.6. Students' writing and pictures

According to Roth, Tobin and Ritchie (2001:90):

> Language and inscriptions are not merely representational devices used to understand an independent nature; they constitute it. Scientists' manipulations and gestures depend both on nature and on current language and inscriptions to become meaningful scientific actions. When they talk to each other, scientists use language, marks on paper (graphs, equations, diagrams, images), pointing, gesture, and movement.

A useful approach to encourage students to write is called CSIW or 'cognitive strategy instruction in writing' (Englart et al. 1991). . In this writing process, the teacher explains and shows examples to students. Students notice teacher reflections and consider the following as Pressley (2003: 345) describes: "Who am I writing for? Why am I writing this? What do I know? How can I group my ideas? How will I organize my ideas?"

Cognitive task analysis provides the opportunity to analyze students' work in terms of common errors found, while a common task analysis might only look at the percentages of right and wrong responses (Mayer, 2003; Brown and Burton 1978). One example is how the writing of students shows commonalities in presenting the concept of electricity using text and pictures.

The analysis of common patterns can give some evidence about the conceptual trends or possible misconceptions in the students' writing (text and pictures). If many students in a certain group show the pictures of electrons and atoms to provide a more explanatory process for electricity, as compared to other students who only write or draw about the use of electricity in daily life, this can culminate into possible types of analysis: (1) the traditional way of calculating the higher and lower numbers; and (2) the types of common errors in terms of observing certain cognitive pattern(s).

In relation to the research question and inquiry design, students' writing is only analyzed from the perspective of the use of certain keywords in both groups. The other related factor is student made pictures to compare the common pictorial structures used to display the concept of electricity. The comparison of common patterns found in the student-made pictures and the use of keywords related to electricity (lexical-conceptual profile and other dimensions) can give some evidence to address the research question. Roth, Tobin and Ritchie (2001:89) assert:

> Discourse (in all its modes) is situated action rather than representational abstraction; that is, we use language to get things done in collectivities rather than merely to encode meanings. Language both makes phenomena and expresses them; new phenomena and new experiences co-evolve. In the same way, diagrams are not just representations of concepts but are integral aspects of situated action.

McCarthey (2008:340) discussed the four writing frameworks (emergent, cognitive, social constructivist, and critical) as:

> The four frames serve to organize the theories, research, and pedagogy that have emerged in the last 30 years about writing. Each model has theoretical strengths and weaknesses in its conceptions of the writer, the processes of composing text, and the instruction that best supports students' learning to write. No single frame for understanding writing can capture the complexity of the process nor completely inform us about the best methods of instruction to enhance the abilities, motivations, and products of writers. But together the frames provide different lenses for reviewing the process, the writer, the context, and the text.

The current theories and standpoints on writing analysis indicate the limitation of a single frame of study and promote the rationale that data can be collected and discussed in relation to a specific research study. The main focus of this study is not writing analysis, therefore only some aspects of student writing are categorized and discussed under various contexts. The overall discussion of results includes student responses and elaborates on some common features of obstacles faced by students in understanding the concept of electricity.

3.7. Rationale for data validity, additional resources use, lexeme frequency and the student group formation

In any such study, it is not completely guaranteed that all students are of the exact same learning level, or that when they are being tested they are at their best level of performance to provide responses to the researcher. Even if a test is conducted to determine their cognitive level, it is not guaranteed that they will display the same learning level in a test situation, interest in a subject, focus in a response, or performance level on that given day (Fraenkel and Wallen 1993:47). Therefore, after forming reasonably compatible student groups, some flexibility factor remains within the given parameters of the research study. In reality, the learners of a textbook come from various levels, so testing the textbook use on multilevel classes is more logical. Classroom composition in the schools under discussion takes place by way of a detailed process. Student reports from the previous class and a summary written by their teacher(s) are prepared for each child. A meeting takes place between the last year and the prospective new teacher along with a principal. Feedback from the guidance department is also considered in some cases. After this, all that data is presented on a big table. The classes are formed (by the team indicated) to make sure there is a balance of students of various levels, genders, and cultures. This collaborative effort provides the opportunity to compose a classroom that has almost compatible grouping for the given academic and social purposes. The textbook analysis conducted on those classes has potential to provide data that comes from a cross-section of student population (in contrast to an entire class of gifted students or one consisting entirely of students with learning challenges). In relation to the textbook study, a mixed composition of students is best suited to see the effect in a multilevel and multicultural population. Nevertheless, this study never claims to be a general outcome for all learners. It is frequently argued that this research work should be viewed within the parameters/varying factors of this study and more research is suggested on larger population samples using large-scale mixed-methods. The study shows more validity, as the student responses can also be seen along with the content analysis data that is also presented for comparison.

Canadian students in the experimental group were given the opportunity to learn from the textbook *Electricity—Science & Technology* (Campbell et al. 1999). In addition, the following books/resources were also used:

● The Oxford Illustrated Junior Dictionary, Rosemary et al. (2000:63)

● The Oxford Elementary School Dictionary, Augarde et al. (1993:140)

● Nelson Canadian Dictionary of the English Language, Green et al. (1998:441)

● Understanding Electricity, National Geographic. Tomecek (2002:31)

● Switched On. Atkinson et al. (1994:16)

● Physical Science in Action (video brochure): Electricity 6, Schlessinger et al. (2000)

● The Harcourt Brace Canadian Dictionary for Students, Smith et al. (1997:175)

● The World Book Student Discovery Encyclopedia (p.111-112)

● Electricity & Magnetism, Parker (2005)

● Electricity and Magnetism, Whyman (2005)

● Circuits Shocks and Lightning, Peters (2000)

In contrast, students in the control group had the opportunity to learn in the conventional way using the textbook CT, which was being analyzed. This contrasting factor in the experimental study provides the opportunity to explore the students' responses when the textbook use is augmented with additional learning resources. The additional learning resources may facilitate the textual and graphic explanation with science related concepts and perhaps work for situation models (cf. Tapiero and Otero 2002).

The student class formation in the schools of Pakistan, in which this study was conducted, did not have a vigorous process for class formation. In general, the teachers did place students of various levels in each class with the consent of school administration. The student population was all male Grade 6 students; therefore it was not possible to see any varying factors in the students' responses with male and female respondents. Locally published science textbook PT chapters on Electricity were used in the control group, while the experimental group studied using the same textbook along with additional resources same as applied in the Canadian study (list is given above).

From a critical perspective the question arises as to whether it is possible that the data collected by counting the frequency of lexemes (key words) and sentence classification (with reason or without reason) can provide the hidden details of overall meaning that the textbook authors tend to provide. In the 21st century when we explain the concept of electricity to grade six students, we need to explain the scientific processes leading to this phenomenon to facilitate explanatory understanding (within the conceptual framework for the given population of the learners). If the textbook shows no use of such words as "electrons" and "atoms" then an important inference can be made about missing the opportunity to explain the concept of electricity using scientific reasoning. The other possibility is if the textbook has sparse information on electrons, then inference can also be made about the lack of explanatory text indicators. Newton et al. (2002) also use this type of inference by calculating the clause frequencies in the textbooks.

3.7.1 The role of additional resources in comparison to the textbook use

The educational policies prescribe various strategies for using classroom materials in the given classrooms. The extended variables exist due to various needs of the local population. For example the province of Ontario provides curriculum expectations and the delivered curriculum and received curriculum can bring so many varieties. The Ontario Ministry of Education also recommends the Electricity textbook CT on their webpage, at the time this information was noted. According to the authors of the textbooks, this textbook has the closest match with the provincial curriculum (Alexander et al. 2000). Some other types of examples include the province of Alberta in Canada, where the use of a textbook is not compulsory. Regarding the case of Alberta, Rowell and Ebbers (2004:218) remark:

The government does not mandate instructional resources and no textbook is prescribed for instruction. Instead, a collection of teacher and student print resources are ‘authorized’ for use in classrooms, their selection being at the discretion of individual teachers, in consultation with colleagues and school administrators.

In order to explore the effects of such an approach, Rowell and Ebbers (2004) conducted a case study in grade six classrooms in Alberta, where the use of the textbook is not mandated. The macro and micro-classroom contexts were studied with focus on the interactions between curriculum statements given in the policy, assessment procedures in place at the provincial and district levels, and teacher resources and teacher implementation of such frameworks. In the absence of textbooks, teachers expressed a higher-level need for the printed materials to support learning. The results of this study prove that “the pedagogical discourse resulted in limited experiences with available print resources and, in turn, constrained the possibilities for school science” (ibid.:217). The researchers of this study in Alberta also point to the need of oral explanation, which is supported with feedback from the students’ writings. Otherwise, the absence of such process can effectively disengage students from the scaffolding. The structure of this study shows that without textbooks teachers relied intensely on other print material or additional resources. Despite designing such materials with the consultation of teachers, there were some pedagogical concerns. Rowell and Ebbers (2004:227) assert that “the findings of this study point to a need to address both the role of textual resources in school science, and the orientation of experiences with print in science lessons.” This study emphasizes the importance of bridging the gaps between text and classroom experiences. The essential cognitive factor is that if the text does not have the required and clear explanation of the science concepts, relying only on classroom experience can be limiting. The discussion in light of this study concludes supporting arguments for comparing student learning using only a textbook, and learning from a textbook along with other resources. This was also the case in the current study on the textbooks CT and PT. The experimental group used the textbook and additional resources (list of the additional resources is given in the subheading 3.7), while students in the control group used just the textbook.

Rowell and Ebbers (2004:227) conclude that “this study suggests that further research is required to explore the mediation of textual resources as sites of inquiry and as tools of inquiry in school science.” The textual resources as sites of inquiry are also partially related to document analysis. This component can elaborate the possible outcomes related to learning from a text. As indicated in the study, teachers have shown high demand for textual support to inculcate the grade six science concepts. The heavy reliance on the text increases the need for the accuracy and explanatory nature of the text. On the other hand, textual resources as tools of inquiry are partially related to the effectiveness of conceptual interface of the learning process. The response from the learner is important feedback from which to analyze the reflection of conceptual links.

The other conclusion of Rowell and Ebbers (2004:227) is that “there are strong indications that teachers need support in developing confidence to explore the ambiguities of language, rather than striving to fix meanings through labels and definitions." The semantic and syntactic ambiguities of science-language are closely associated with the explanatory sentences and facilitating reasoning of science concepts beyond the everyday observation of the phenomenon. The conclusion of Rowell and Ebbers (2004) reinforces the need to develop support for teachers to come out of the ambiguity associated with the textual framework and science-related concepts. The wide range of cognitive factors that work with concept formation functions and the real-life available resources in a given classroom are two important aspects of theory, research, and practice. The rationale for providing enhanced support to teachers when they heavily rely on the textual component is further echoed with the improvement in the explanatory nature of the text. The quality of the text as a medium for conveying science concepts depends on various cognitive, educational policy and curriculum methods. The textual tools cannot deliver all conceptual details as a self-reflecting body of knowledge if the science concepts and other didactic and pedagogical factors are not addressed. Conversely speaking, if grade six science teachers rely heavily on the textual resources as indicated by Rowell and Ebbers (2004), the need to incorporate textual accuracy, with the explanatory nature of science becomes a linguistic, cognitive, and, pedagogical continuum that thrives with theory, research and practice. According to Koulaidis and Tsatsaroni (1996:70)

> Empirical research work in the field of textbooks needs to be supplemented by theoretical considerations. For there still remain very important questions to be asked regarding the school textbook, and very significant insights to be gained from fields such as science and mathematics education.

In consideration of the recommendation made by the research study of Koulaidis and Tsatsaroni (1996), a research design in relation to the current theoretical consideration trends can be more effective in the interdisciplinary fields, particularly where content analysis and student responses are the focus of analysis. Some of the challenges for the elementary and middle school level children for science textbook comprehension are stated by Best et al. (2005:70-71):

> Students of all ages have been found to experience difficulty comprehending and learning from science texts. The problems with science textbook comprehension, however, are particularly pertinent among young students at the elementary-school and middle-school level, when children are first exposed to them. Science texts contain difficult vocabulary and syntax, and also place greater emphasis on inferential thinking and the use of prior knowledge. The increased exposure to challenging expository materials, including science textbooks, at a time when domain knowledge is still developing places greater cognitive demands on young readers, and may account for some of the reading comprehension difficulties experienced by children in the third to fifth grades, which is sometimes called the fourth-grade slump.

Currently, there is no single evaluation measure or method that can rectify the varied nature of comprehension difficulties children may experience using a science text (cf. Best et al. 2005; Hartman and Glasgow 2002; Hartman 2001). The researchers, teachers, authors and other users can continue to communicate, evaluate, analyze texts, and innovate to constantly improve the process and resources of learning science for elementary level students (cf. Lee 2007; DiGiuseppe 2007).

Summarizing, in the context of this study, there were different teachers who taught experimental and control group in different classrooms. Both teachers were certified with same qualifications to teach science at this grade level, in the given location. The topic of electricity was taught for six weeks. The control group used the relevant textbook while the experimental group used the relevant textbook and at the top some other resources (for which list is given previously). Those resources were available in the classroom for all students. This learning environment was helpful to see if the learning only from the relevant textbook will show certain response from the students (control group) in contrast to if the students were given some added resources (experimental group). The 25 key-words compared from both textbooks and from the experimental and control group, in both studies, were the same. This factor also provides an opportunity to compare the presence or absences of certain key-words from the textbook and the reflection of those 25 key-words in the students' writing. This information is useful to see the external validity of the research.

3.8. The limitation of the study

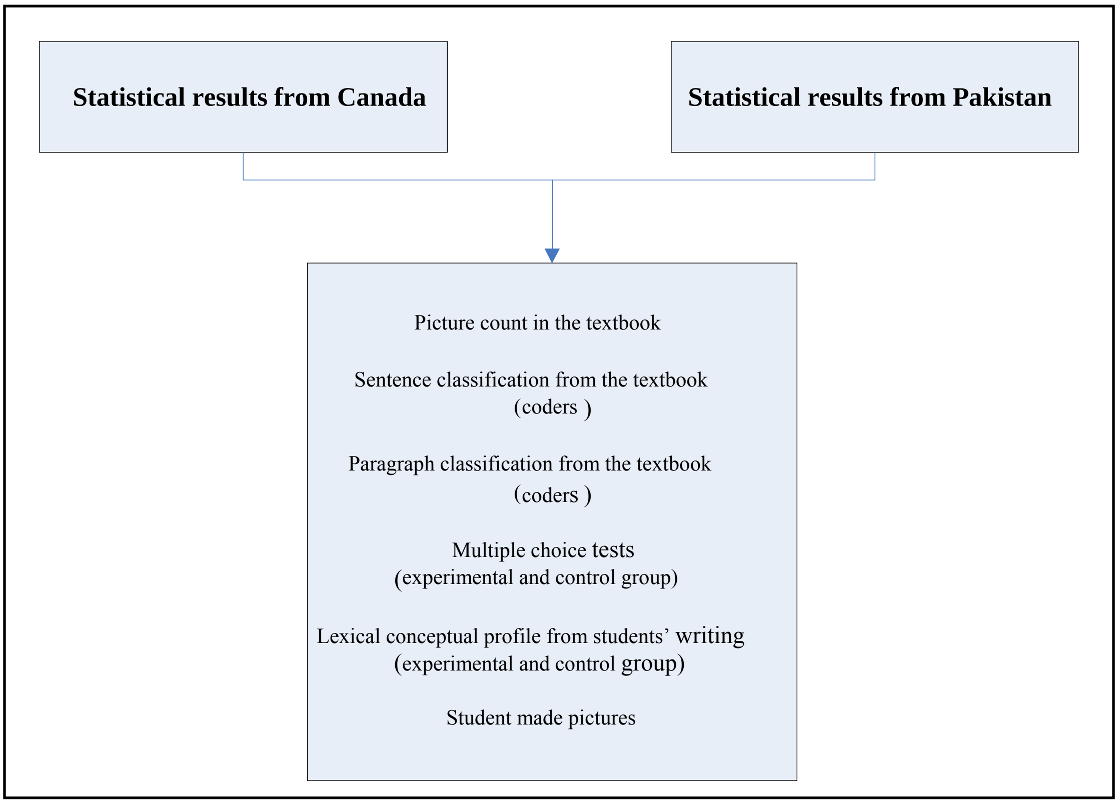
The current study applies a combination of strategies with some adjustments to fit the model of this study (Figures 6 and 7). As discussed above, those methods are used in some form by many researchers. The researcher has applied a variety of tools for textbook analysis to reduce possible chances for bias. The analysis includes sentence classification, paragraph analysis, lexical-conceptual profile, as well as the study of applying an empirical method on two groups of 60 students (from Pakistan and Canada) and comparing the learning of these students using a multiple choice test and other work. The teaching system of Pakistan and Canada varies in the scope of policies, social aspects, curriculum designing, classroom settings and curriculum delivery. Despite those variations, the textbook topic on "electricity" provides interesting data in terms of student reflecting their understanding after working with the textbook and the way student responses change after they interface with using some additional learning resources provided from Canada.

Every teacher in the classroom brings their own learning style to some extent. The variety of all students' cognitive styles cannot be reached by any one way of testing. The possibility of students using other resources for learning at home (for example, TV Internet, discussions with parents) may bring some influence in their learning and responses. However, the data shows some stability in terms of consistently finding some specific student patterns for explaining the term ‘electricity’ in one group as compared to the other. The sentence classification of textbooks (from Pakistan and Canada) shows precise comparison of each sentence and shows clear need for improvements. However, the comparison of all patterns of student comprehension patterns in Canada and Pakistan goes beyond the scope of this study.

Chapter 4 DATA COLLECTION AND ANALYSIS

The following figure shows the frameworks and the data collected.

Figure 8: Data frameworks for the studies from Canada and Pakistan



This chapter presents data collected from the various frameworks of the study. The first section presents data collection from Canada and the second section includes data from Pakistan. For both studies, the textbook content analysis is presented before the student responses (sentence analysis, paragraph analysis, keyword analysis). After the content analysis data various frameworks on student responses are included. The multiple choice test was the same for both studies. For the multiple choice test, the statistical analysis comparisons are presented with t-Test, mean and other measures to show the numeric distinctions of the data. The next portion presents data collected from the students' writing with the frequency of occurrence of certain keywords followed by the Tables, radar charts, and graphs. The student made pictures are also presented in terms of certain group of pictures. The study from Pakistan also includes data factors in the same way.

4.1. Picture Count in the Textbook

The Table 3 shows a picture count in the textbook (CT). This is important because pictures also work as subheadings (Mandl and Levine 1989). The effectiveness of pictures and their types is an issue that can be debated from various standpoints. The details of picture analysis are not the focus of this study. This analysis just shows the number of pictures used in this size of book.

Table 3: Picture Count in the textbook

Circuit Diagrams (Black and White)	Camera/computer pictures	Charts
9	62	9

According to Alesandrini (1984), instructional pictures can be divided into the following categories; arbitrary pictures, analogical pictures and representational pictures. Representational pictures are camera pictures; analogical pictures show the actual idea with the help of an example of something else (e.g. cartoons); and, arbitrary pictures include web charts, flow charts, and tree diagrams. Alesandrini (1984) categorizes camera pictures as ‘representational pictures,’ however the question arises: if a picture represents something why do we have to name only camera pictures as ‘representational?’ Therefore, naming only camera pictures as ‘representational’ may lead to some ambiguity. Analogical pictures can also be designed in the form of web or tree diagrams; therefore, some overlap may also appear about the names of ‘analogical pictures’ and ‘arbitrary pictures’. For the current analysis (Table 2), pictures were only classified as circuit diagrams (black and white), camera/computer pictures, and charts. The camera/computer pictures represent the largest group (62). The purpose of those pictures might be to elaborate the concepts given in the text (or vice versa), encourage students to make connections with the previous knowledge and learn through interesting icons. Circuit diagrams (black and white) and charts both total nine per group. The numbers of those pictures are significantly low as compared to the camera/computer group (including handmade pictures). Analogical pictures also facilitate to convey some abstract ideas of science, for example an analogical picture with people swimming in a circle can also be related to the concept of revolving electrons. The textbook analyzed on electricity shows a clear deficiency of such pictures that can facilitate the understanding of electricity as flow of electrons.

4.2. Sentence classification of the textbook

The following chart will show the sentences of the **Canadian textbook** and categorize them in the following two main categories:

(1) Sentence without providing a reason.

(2) Sentence providing a reason.

Exercises for children and assignment pages not included in the sentence classification. The rationale is to compare how the elements of explanatory sentences are included in the text. Table 4 shows examples of sentence classifications. The detailed sentence analysis is given in Appendix 3A.

Table 4: Example of sentence classification of the textbook

(Note: A sentence that provides no reason is classified as **WR** (without reason), a sentence that provides a reason is classified as **R** (based on Newton et al. 2002: 228))

Sentences from the textbook	**WR**=without reason **R**= reason
Electricity.	WR
It's all around you.	WR
It’s invisible.	WR
It can be used for many purposes such as listening to music, finding your way down a dark path, or talking to a relative in another part of Canada.	WR
As the temperature goes down, the bi-metal strip bends and moves the switch to the right.	R

The Table 5 provides specific sentence categories found in the textbook (CT).

Table 5: Classification of textbook sentences in two categories

No.	Type of sentences	Count	Percentage
1	Sentences provide no reason (WR)	357	87.93%
2	Sentences provide a reason (R)	49	12.06%

In order to enhance the stability of the data, three coders analyzed the data and their analysis has close patterns of concordance.

<u>Coders Responses on Sentence Analysis</u>

● Teacher A [coder 1]: Results are given in Table 5 and more details are given in the Appendix 3A.
● Teacher B [coder 2]: Results were all the same as coder A, only in sentences 4, 24, 76, 163 it was the opposite to coder A.
● Teacher C [coder 3]: Results were all the same as coder A, only in sentences 328, 337 it was the opposite to coder A.

As a general comparison this shows a high level of close occurrence patterns in the analysis of three coders.

The above analysis shows that a large percentage of sentences in the textbook are “without reason-bases” (WR). Those sentences describe certain pieces of information or make simple statements, but do not give substantial reasoning as to why something happens or what the scientific explanation is. As Bloom’s Taxonomy (Anderson 2003) shows, a higher level of thinking is associated with reasoning and analysis. Therefore, perhaps sentences that do not explain reason(s) cannot facilitate explanatory understanding. Some standardized tests in the elementary schools also emphasize on higher level thinking and analysis skills. The higher number of "without reason-based" sentences also indicate an opportunity missed to inculcate reasoning and make further comparisons. Some evidence of student responses will be shown in the following frameworks of the study.

Any sentence that provides a reason is categorized as "reason-based" sentence, while in terms of linguistic characteristics some of those sentences can also be classified as "cause-and-effect." That notion, however, does not imply a clear conceptual formation of the explanatory nature of "electricity." There may not be a direct philosophical link between the higher number of "reason-based" sentences and student understanding of the concept of electricity, providing reasons for a scientific concept (such as electricity in this case). The pedagogical base for science teaching needs reason(s) to explain certain things, rather than just the simple collection of facts (Brewer et al. 2000; Newton et al. 2002). The performance of the students in the experimental group and control group can probably explain further links to this process. Newton et al. (2002) have also found a lack of concern for explanatory understanding, using clause frequency occurrence in many textbooks that were analyzed. The current study also reinforces this fact for the specific textbook analyzed on the topic of electricity.

Newton et al. (2002:230) show the relationship between the type of clauses found in a textbook and their explanatory nature:

> We would expect to find clauses of cause or purpose because such clauses commonly supply or ask for reason in science. It may be possible to convey or request reasons without such structures but it seems perverse for a writer to avoid them when that is their function. Further, we expect that the more a book is concerned with explanatory understanding, the greater the chance of finding such structures. This is not to say that there is a direct or simple relationship between concern for explanatory understanding and the frequency of occurrence of such clauses. Nor is it to say that there can be no explanatory understanding without such structures.

In view of this standpoint, there is no simple relationship between the "reason-based" sentences and explanatory understanding (Newton et al. 2002), because human understanding has many cognitive and social factors involved in the learning process. However, a higher number of (balanced composition) sentences with 'reason base' style may enhance explanation of reasons in a science textbook. Overall, there are smaller numbers of sentences that come under the 'reason based' category, which is a possible reason to find a lack of concern for reasoning given in the textbook to elaborate scientific phenomenon (electricity and related ideas). More evidence is substantiated as there is not even one sentence in the textbook that describes electricity as the flow of electrons, nor does it gives explanation and picture to support this process. While the experimental group came to find such descriptions in other books (the experimental group used other resources and not just this textbook), it is most likely that the control group could not get basic information on this idea from the textbook under analysis. This process is further supported by the data collected for other frameworks.

4.3 Lexical-conceptual profile

By searching some common definitions of the word 'electricity' and the focus of this research, 25 words were selected. The criterion to select those key words is based on their repeated use in the common definitions to explain the concept of electricity along with the words *repulsion* and *matter*, which can be used with the words *attraction* and *electrons*. Those 25 lexemes or keywords can show some reflection of certain conceptual variations in the textbook. The textbook is analyzed to find the number of occurrence of those 25 keywords. A textbook on the topic of electricity would more likely use the word 'electricity' or its derivatives in a larger number. This textbook has the same case. The highest number of word occurrence among the 25 keywords is 'electricity, electric, electrical' (2.16 % absolute frequency and 41.02% relative frequency). The second largest word occurrence is 'light' (73% absolute frequency) and the third largest word occurrence is the word 'energy' (72% absolute frequency). Following this group, the next lower percentage category appears for the word 'wire(s)' (68% absolute frequency) and the words 'battery/batteries' (53% absolute frequency). The use of some words in the textbook associate with the use of electricity (such as 'wire' or 'battery'), but do not necessarily explain the reasoning of what processes happen behind our common observations. It is notable that rest of the word groups are very low in numbers, such as 'heat/heating' (13% absolute frequency), 'work' (11% absolute frequency),'power' (9% absolute frequency), 'conduct/conductor' and 'matter' (7% absolute frequency) each. Among the smaller groups are the words 'flow/flowing' and 'current,' which appear only 0.0290% (absolute frequency). Words that were counted for only 0.0097% absolute frequency are 'movement,' 'form,' and 'machine.' A very striking observation is the complete omission of the following words: electron(s), atom(s), radiation, electromagnetic, physical, protons, attraction, particles, charge(s), and repulsion. The lexemes that appeared with a zero frequency are not included in the bar graph and radar chart. They are given in the Table 6.

These data is also shown in the following bar graph (Figure 9), in which zero frequency items are not included, and in the following radar graph (Figure 10), in which zero frequency items are not included.

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Table 6: Lexical Conceptual Profile from the Canadian textbook (n = 10350 words total)

Keywords	Word Count	Relative Frequency (out of 10350 words)	Relative Frequency (out of 546 words used)
1. Electron(s)	0	0%	0%
2. Atom(s)	0	0%	0%
3. Radiation	0	0%	0%
4. Electromagnetic	0	0%	0%
5. Physical	0	0%	0%
6. Protons	0	0%	0%
7. Attraction	0	0%	0%
8. Particles	0	0%	0%
9. Charge(s)	0	0%	0%
10. Repulsion	0	0%	0%
11.Machine	1	0.0097%	0.18%
12. Movement	1	0.0097%	0.18%
13. Form	1	0.0097%	0.18%
14. Current	3	0.03%	0. 6%
15. Flow/flowing	3	0.0290%	0.55%
16.Matter	7	0.0676%	1.28%
17.Conductor/conduct	7	0.0676%	1.28%
18. Power	9	0.0870%	1.65%
19. Work	11	0.1063%	2.01%
20. Heat/heating	13	0.1256%	2.38%
21. Battery/Batteries	53	0.5121%	9.71%
22. Wire(s)	68	0.6570%	12.4542%
23. Energy	72	0.6957%	13.1868%
24. Light	73	0.7053%	13.37%
25. Electricity, electric, electrical	224	2.1643%	41.0256%

(Percentage rounded)

Figure 9: Lexical-conceptual profile from the textbook

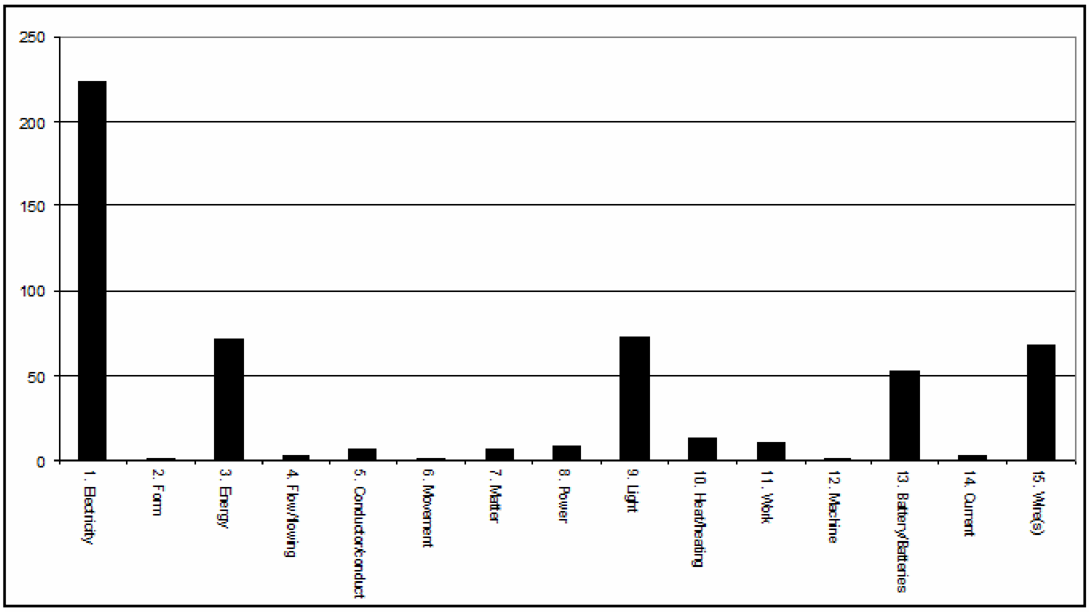
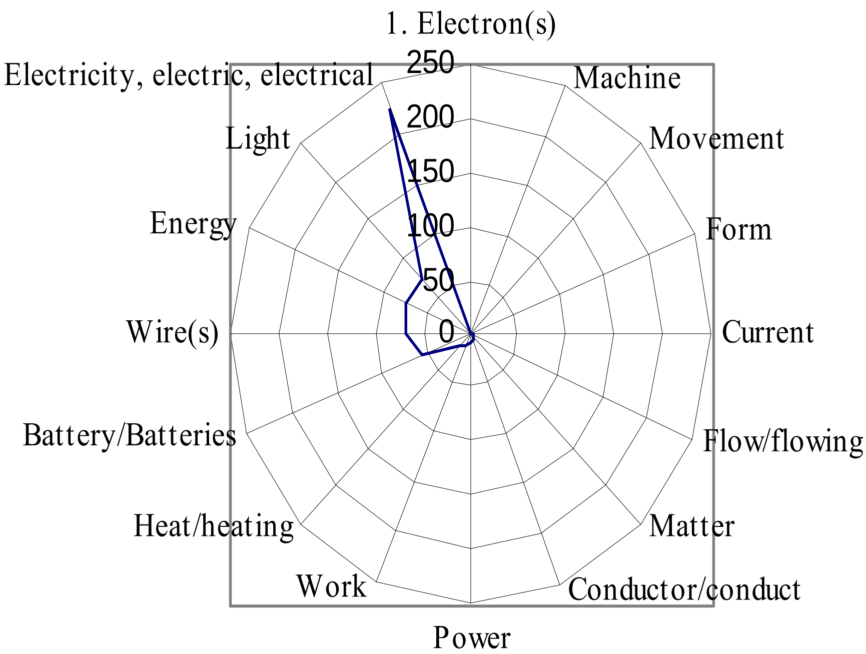


Figure 10: Lexical-conceptual profile from the textbook



While comparing some common dictionaries of children, it is noted that some dictionaries do not refer to the word 'electrons,' while some dictionaries use the word 'electrons.' However, the explanatory nature of the meaning (beyond to common observation phenomena) or just understanding the common links to the word in real life (where the use of electricity is observed) is an important issue for improving explanatory understanding. Some examples of commonly used dictionaries or children's books are:

● Electricity: "the power or energy used to give light and heat and to work machines. It comes along wires or from batteries." (The Oxford Illustrated Junior Dictionary, Rosemary et al. 2000:63).
● Electricity: "a kind of energy used for lighting, heating, and making machines work." (The Oxford Elementary School Dictionary, Augarde et al. 1993:140).
● Electricity (1.a): "the physical phenomena arising from the behaviour of electrons and protons caused by attraction of particles with the same charge" (Green et al. 1998:441, Nelson Canadian Dictionary of the English Language).
● Electricity: "a form of energy that can flow through conductors" (Campbell, 1999:44, Science & Technology, Electricity).
● Electricity: "a form of energy that involves movement of electrons" (Tomecek 1998:31, Understanding Electricity, National Geographic).
● Electricity: form of energy produces by the movement of electrons from one atom to another. It can be converted into light, heat, and movement (Atkinson et al. 1994:16 Switched On).
● Electricity: Electromagnetic radiation that is visible to the human eye (Physical Science in Action: Electricity 6, Schlessinger, Video).
● Electricity: A form of energy that is produced by a current of electrons flowing quickly through a wire or other objects. (The Harcourt Brace Canadian Dictionary for Students: 175).
● Electricity: Electricity is a kind of energy. (The World Student Book Encyclopedia: 111).

Many of the given definitions do not use the word 'electron(s).' Some authors may have used a general notion to describe the word electricity. As the concept of electricity is best described by explaining the flow of electrons, this omission is a missed opportunity for outlining the concept with more scientific reasoning. The Table 7 shows some examples of paragraph coding examples with classification of paragraphs shown in the Table 8.

In order to enhance of stability of the data three coders analyzed the data on their own. Coders' responses on paragraph analysis indicate the following results:

● Teacher A [coder 1]: Results are given in Table 7 and more details are given in the appendices.
● Teacher B [coder 2]: Results were all the same as for Coder 1, only in paragraph 9 it was category 1 and in paragraph 46, it was category 1 and 2.
● Teacher C [coder 3]: Results were all the same as for Coder 1 only in the paragraph 55 it was category 1, and in paragraph 58 it was category 1 and 2.

As a general comparison this shows a high level of close occurrence patterns in the analysis of three coders.

Table 7: Paragraph coding examples

(1) discusses daily life use of electricity, electricity resources; (2) asks readers to ‘think about’, ‘ imagine’, ‘don’t you think’, asks questions, asks to identify, asks to compare; (3) explains something using reason(s); (4) Includes numeric values (2 km, 1000 kWh, 1888 AD)

	Paragraph (examples)	1	2	3	4
1	Electricity. It's all around you. It’s invisible. It can be used for many purposes such as listening to music, finding your way down a dark path, or talking to a relative in another part of Canada. You will participate in an electric adventure as you learn about electricity.	X			
4	Review the drawing of your fridge with others in your class. Aren't you glad that we have access to electrical devices like fridges, ovens, and computers? How did humans discover and harness electricity? Believe it or not, it all started with a frog's leg, a brass hook, an iron railing, and a lightning storm.		X		

Table 8: Paragraph analysis (83 paragraphs in total)

No	Content Category	Count	Percentage
1	1	37	44.6 %
2	2	33	39.7%
3	3	7	8.4%
4	4	21	25.3%

The Table 9 shows which paragraph categories (CT) were repeated with another content category of the other paragraph(s). The highest amount of overlap was found in the category 1 and 2 and 1 and 4. The least amount of overlap was found in the category 2 and 3 and 3 and 4. The most common overlap in category 1 is related to the word electricity in every day use perspective.

Table 9: Paragraph overlap of categories

No	Overlap	Count	Percentage
1	1,2	6	7.2%
2	2,3	1	1.2%
3	2,4	4	4.8%
4	3,4	1	1.2%
5	1,3	2	2.4%
6	1,4	6	7.2%
7	1,2,4	2	2.4%

4.4. Common multiple choice test

The multiple choice test (included in Appendix 1) was an attempt to reflect on students' understanding about the following items:

-To see the links between electrons and electricity
-To observe any indicators about the structure of atoms and electricity
-To observe if students can link generation of electricity using nuclear energy
-To show the link to the scientific terms power and energy
-To distinguish between static and current electricity

One of the focuses of this objective test was to analyze students' understanding on the above mentioned items. The test was designed in such a way that students required to have clear understanding of the concepts or else they may get confused with the way sentence was designed and asking for a yes or no about this item. The rationale from the overall results was to explore some pathways to improve the science textbooks for elementary level students. This test was conducted after six week unit completed on electricity using the related textbook for this study. Students were given the same test in control and experimental group. There were two groups of Grade six students comprised of 60 in each group from Canada and Pakistan. At the end of teaching unit on electricity, students were given a multiple choice test to reflect their understanding of the concepts learned about 'electricity.' Based on the statistical analysis, results show students in the experimental group performed better than the students in the control group. There were only two questions (numbers 1 and 3) where both groups had an equal number of correct answers. Among all 19 questions, there was no question is which control group students performed better than the experimental group. The student responses for all 19 items of the multiple choice test are given in Table 10 from the experimental and control group of Canada.

Table 10: Multiple Choice Test, Student Responses n=60 in each group

Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Correct Responses (Experimental Group) n=60	58	48	52	52	57	47	41	26	60	48	54	55	24	49	40	54	44	41	40
Correct Responses (Control Group) n=60	56	33	52	35	43	42	32	24	54	39	43	45	16	30	33	41	37	32	29

A common multiple choice test was given to both groups (experimental, n=60; and control, n=60) to show what they understand about the concepts analyzed. Hypothesis testing for the mean difference between experimental and control group scores using t-Test:

μ_E = Hypothesized mean for Experimental Group
μ_C = Hypothesized mean for Control Group

The null hypothesis, H_0, and the alternative hypothesis, H_1, are given as follows:

H_0: $\mu_E \leq \mu_C$
H_1: $\mu_E > \mu_C$

Choosing a significance level, $\alpha = 0.05$.

The Table 11 shows the summarized data:

Table 11: Mean of multiple choice test

	Mean	Size
Experiment	14.9	60
Control	11.98	60

To test if the two groups are statistically significant or not, we first need to test the equality of the two population variances. Let σ_c and σ_E represent the standard deviation of the control group and experiment group, respectively. The hypothesis is stated as:

$H_0: \sigma_c = \sigma_E;\ H_\alpha: \sigma_c \neq \sigma_E$

The Excel output is copied below (This table is copied from the spreadsheet "Step1-TestVariance"). Since the p-value is 0.30 and it is greater than the significance level 0.05. We fail to reject the null hypothesis which assumes equal variances of the two groups. The details of the two sample variances are given in the Table 12.

Table 12: Two Sample for variances

F-Test Two-Sample for Variances		
	Experiment	*Control*
Mean	14.9	11.98333333
Variance	6.972881356	7.982768362
Observations	60	60
df	59	59
F	0.873491631	
P(F<=f) one-tail	0.302553343	
F Critical one-tail	0.649368947	

Therefore, using Excel's data analysis for independent t-Tests assuming equal variances, we obtain the following (Table 13 and Table 14) results.

Table 13: t-Test for multiple choice test (experimental and control group)

t-Test: Two-Sample Assuming Equal Variances	Experiment	Control
Mean	14.9	11.98
Variance	6.97	7.98
Observations	60	60

Table 14: Pooled variance for multiple choice tests

Pooled Variance	7.48
Hypothesized Mean Difference	0
df	118
t Stat	5.84197617
P(T<=t) one-tail	2.33048E-08
t Critical one-tail	1.657869522

From the Table 14, since the p-value = 2.33×10^{-8} (that is 0.000000233) is far less than 0.05, we reject the null hypothesis.

There is sufficient evidence to conclude that the mean of the experimental group is larger than that of the control group.

4.5. Lexical-conceptual profile based on students' writing in both groups

Lexical-conceptual profile refers to the collection of certain keywords that are found in a students writing samples in both groups (experimental and control group). The list of those 25 keywords comes from reviewing the commonly available student dictionaries, textbook glossary, and encyclopedias about frequently used words to describe the word electricity. A special emphasis was given to the keywords that are used to explain reasons rather than just describe common facts. Students were asked to write about their understanding of the word "electricity" and the frequency of those keywords was numerically compared to see an indicator of those words. This frequency also provides opportunities to compare the use of certain keywords by students in the experimental group and the control group. (More statistical details of this topic are given in the Table15 and 16).

4.6. Lexical-conceptual profile (Canadian experimental group)

In relation to the current research, students (n=60 in each group) were not given a formal task to write in the three stages: pre-writing, writing, and post writing. Students were given an open choice to write about their understanding of the term "electricity." Students were encouraged to think about the purpose, the audience, their personal understanding of the term electricity, grouping their ideas, and reflect this in their writing. The explanation of the word electricity was reflected in students' writing in many ways. For example, a student from the experimental group (Canada) wrote:

Electricity is a form of energy. Electricity is nothing but movements of electron. There are two different kinds of electricity, static electricity and current electricity. Static electricity is when two things rub together and create friction. A student from the control group wrote:

> I think this is the best way I would understand electricity and hopefully for other kids. Electricity is a source of energy. Electricity is something you use everyday life.

Students were given the multiple choice test before the writing task that may have given some direction to think about the concepts related to electricity. Some guiding questions before the writing process were related to the students. They were asked to think about who would read this work, and how their ideas could be grouped. The lexical-conceptual profile also explains to some extent the pattern of the use of certain type of keywords by the experimental and control group. As shown in the Table 15 and 16, the experimental group has used more keywords related to atoms and electrons, while the control group has used keywords related to the everyday use of electricity.

Students' writing samples taken from the experimental group show highest number of word frequencies for the keywords: 'electricity, electric, electrical (354). The second highest frequency is 'energy,' and then the third one is 'electrons.' The relative frequency of energy is 12.5 % and for electrons it is 9.4 %. The next highest group after that is 'atoms' (93 word frequency), which stands at 8.0% (relative frequency). The use of the keywords, 'protons' (relative frequency 33), 'particles' (relative frequency 22) is also evident in students' writing work from the experimental group. The lexemes that appeared with a zero frequency are not included in the bar graph and radar chart. They are included in the Table 15 (percentage rounded).

Table 15: Lexical conceptual profile based on students' writing (experimental group from Canada, n=60, male=32, female=28)

Lexical Conceptual Profile (From students' writing)			
Experimental Group			
Keywords	Word Frequency	Relative Frequency (out of 5421)	Relative Frequency (out of 1160 used)
1. Radiation	0	0	0
2. Electromagnetic	0	0	0
3. Physical	0	0	0
4. Attraction	0	0	0
5. Repulsion	0	0	0
6. Matter	1	0.018%	0.086%
7. Machine	2	0.037%	0.17%
8. Work	11	0.20%	1%
9. Movement	13	0.24%	1.12%
10. Conductor/conduct	17	0.31%	1.47%
11. Particles	22	0.41%	1. 90%
12. Wire(s)	25	0.46%	2.16%
13.Power	27	0.50%	2.33%
14. Current	29	0.54%	2.5%
15. Charge(s)	30	0.55%	2.59%
16. Protons	33	0.61%	2.84%
17. Battery/Batteries	34	0.63%	2.93%
18. Flow/flowing	48	0.89%	4.14%
19. Heat/heating	48	0.89%	4.14%
20. Form	58	1.07%	5 %
21. Light	61	1.13%	5.26%
22. Atom(s)	93	1.72%	8%
23. Electron(s)	109	2 %	9.40%
24. Energy	145	2.68%	12.5%
25. Electricity, electric, electrical	354	6.53%	30.52%

The Figure 11 shows the data of lexical-conceptual profile based on students' writing in the experimental group in the form of a bar graph. The Figure 12 shows the data of lexical-conceptual profile based on students' writing in the experimental group in the form of a radar graph.

Figure 11: Lexical-conceptual profile based on students' writing (experimental group)

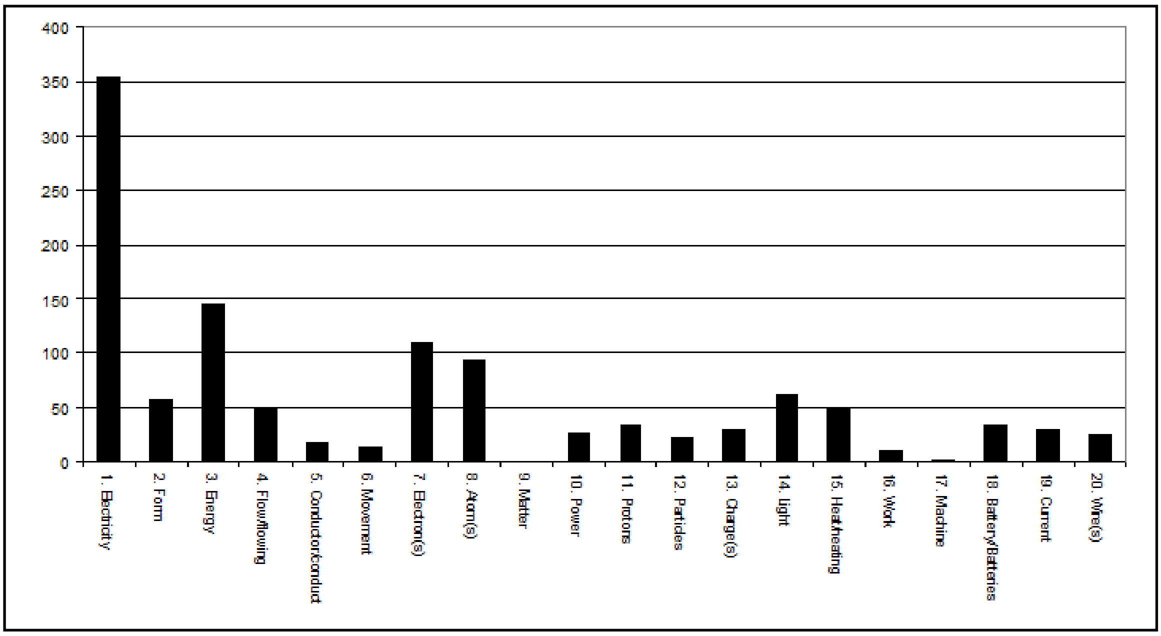
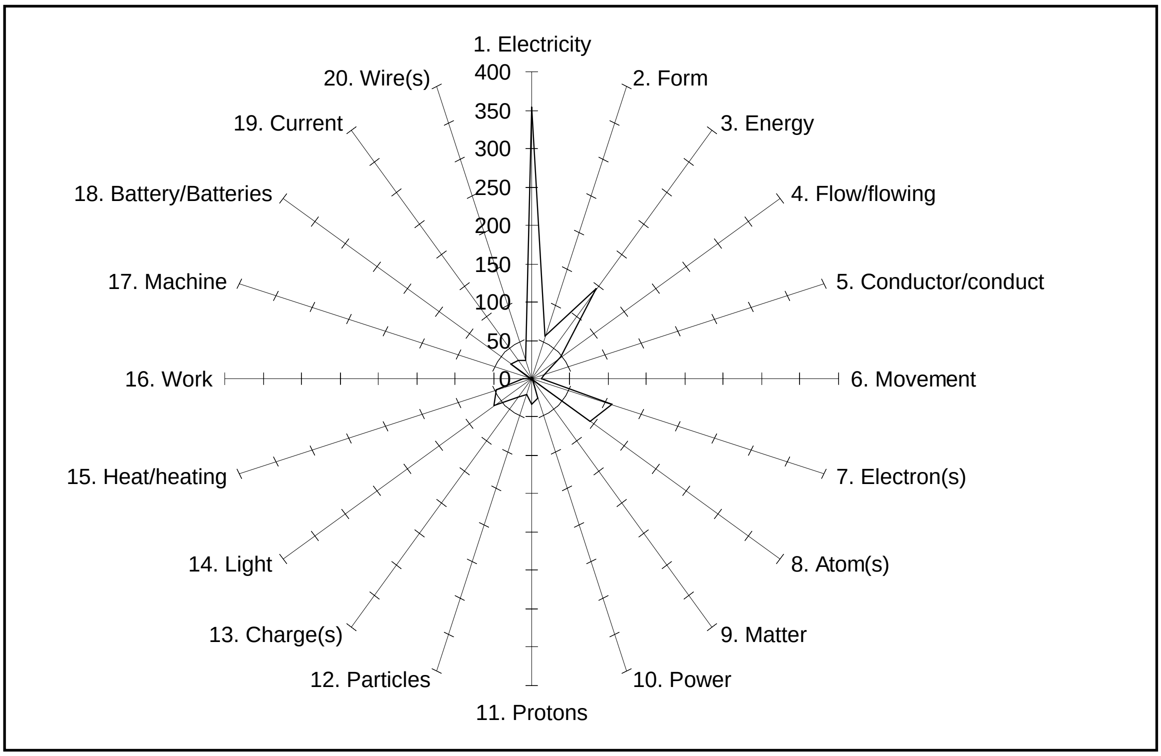


Figure 12: Lexical-conceptual profile based on students' writing (experimental group)



4.7. Lexical-conceptual profile (Canadian control group)

Students' writing work from the control group shows highest number of word frequency is 'electricity,' 'electric,' 'electrical' (relative frequency 93 or 41.0%). The next highest group of frequencies is 'energy' (19.39%), 'light' (11.0132%), and 'form' (5.2863%). It is notable that there is zero word frequency found in the students' writing (control group) work for the keywords: 'current,' 'machine,' 'work', 'repulsion,' 'particles,' 'attraction,' 'physical,' 'electromagnetic,' 'radiation,' and 'matter'. On the other hand, the experimental group has zero frequency for the keywords: 'radiation,' 'electromagnetic,' 'attraction,' and 'repulsion.' The common keywords with zero frequency in both groups are: 'radiation,' 'electromagnetic,' 'physical,' 'attraction,' and 'repulsion.' There is no keyword that had zero frequency in the experimental group, but it was found in the control group. Comparing data from the Table 15, 16 and Figure 15 it is clearly notable that students in the experimental group used more keywords such as: electrons, protons, and atoms. The lexemes that appeared with a zero frequency are not included in the bar graph and radar chart. They are included in the Table 16. Overall, students in the experimental group used more keywords than in the control group. Students in the control group were taught using a textbook that has less or no use of some of those keywords. In contrast, students in the experimental group used the same textbook, but supplemented their learning with other resources that explained the process of electricity in terms of electrons and atoms. Perhaps the learning pattern of the students has played a role to shape their use of keywords in their writing (further discussion under subheading 5.4.4.).

Table 16: Lexical conceptual profile based on students' writing (control group, n=60, male=29, female=31)

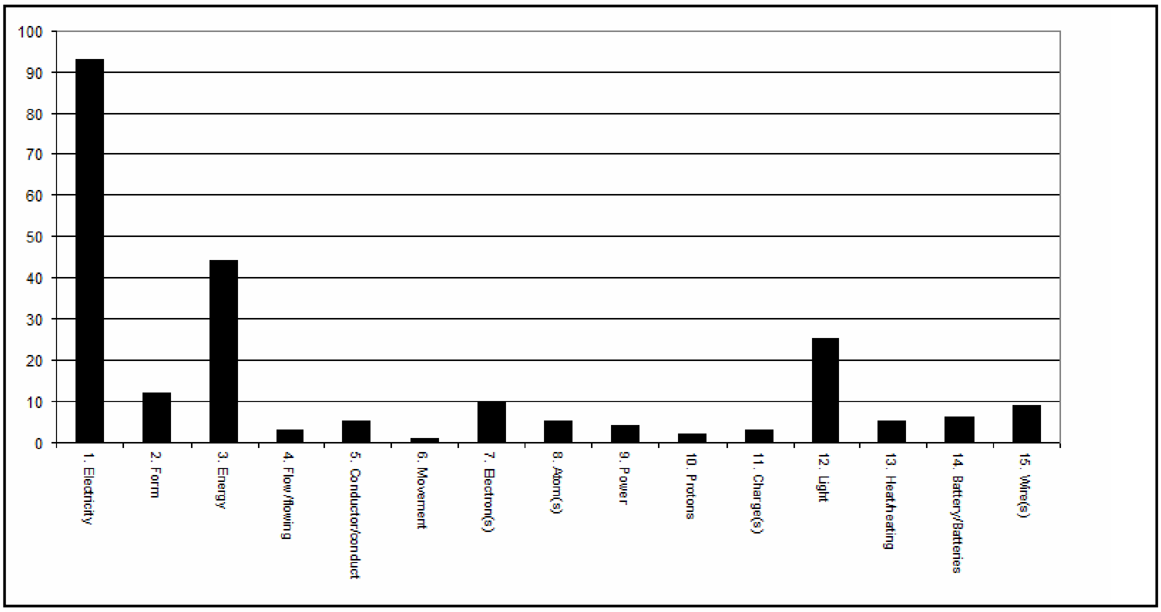
Lexical conceptual profile (From students writing)			
Control Group			
Keywords	Word Frequency	Relative Frequency (out of 1295)	Relative Frequency (out of 227 words used)
1. Matter	0	0 %	0%
2. Radiation	0	0%	0%
3. Electromagnetic	0	0%	0 %
4. Physical	0	0%	0 %
5. Attraction	0	0%	0 %
6. Particles	0	0%	0 %
7. Repulsion	0	0%	0 %
8. Work	0	0%	0 %
9. Machine	0	0%	0 %
10. Current	0	0 %	0 %

11. Movement	1	0.08%	0.44%
12. Protons	2	0.2%	0.88%
13. Charge(s)	3	0.23%	1.32%
14. Flow/flowing	3	0.23%	1.32%
15. Power	4	0.39%	1.76%
16. Heat/heating	5	0.39%	2.20%
17. Atom(s)	5	0.38%	2.20%
18. Conductor/conduct	5	0.39%	2.20%
19. Battery/Batteries	6	0.46%	2.64%
20. Wire(s)	9	0.70%	3.97%
21. Electron(s)	10	0.77%	4.41%
22. Form	12	0.93%	5.29%
23. Light	25	2%	11%
24. Energy	44	3.40%	19.38%
25. Electricity, electric, electrical	93	7.18%	41%

(Percentage rounded)

The Figure 13 shows the data of lexical-conceptual profile based on students' writing in the control group in the form of a bar graph.

Figure 13: Lexical-conceptual profile based on students' writing (control group)



The Figure 14 shows the data of lexical-conceptual profile based on students' writing in the control group in the form of a radar graph. The Figure 15 presents the lexical conceptual profile of the experimental and control group in a bar graph (Canada study).

Figure 14: Lexical-conceptual profile based on students' writing (control group)

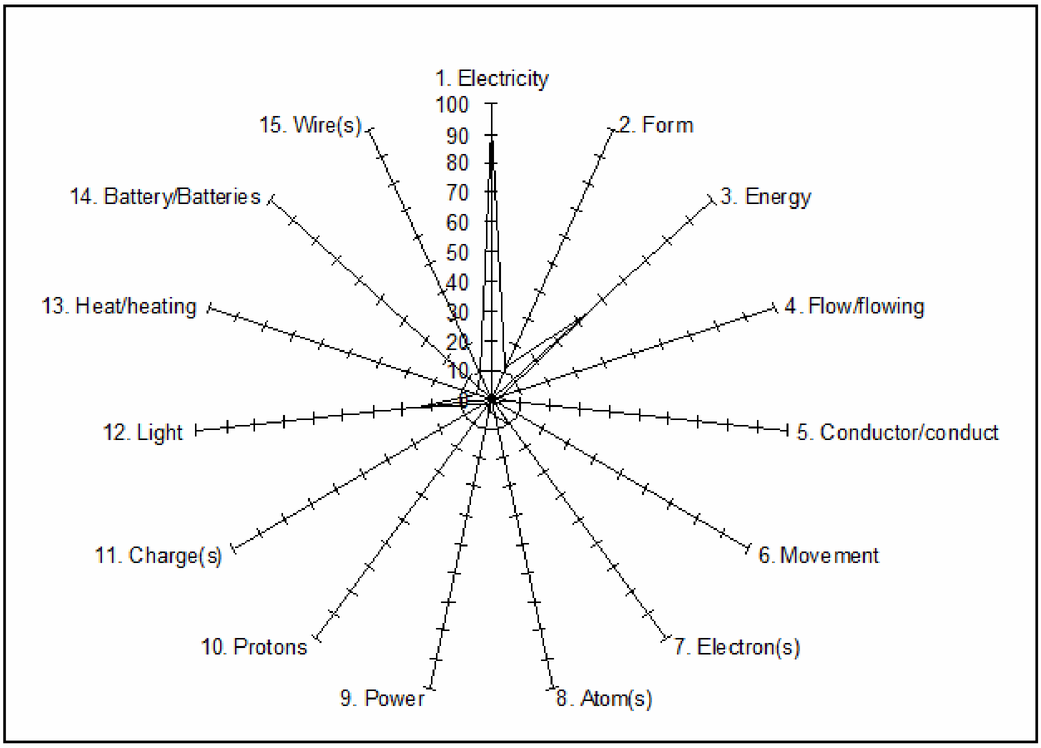
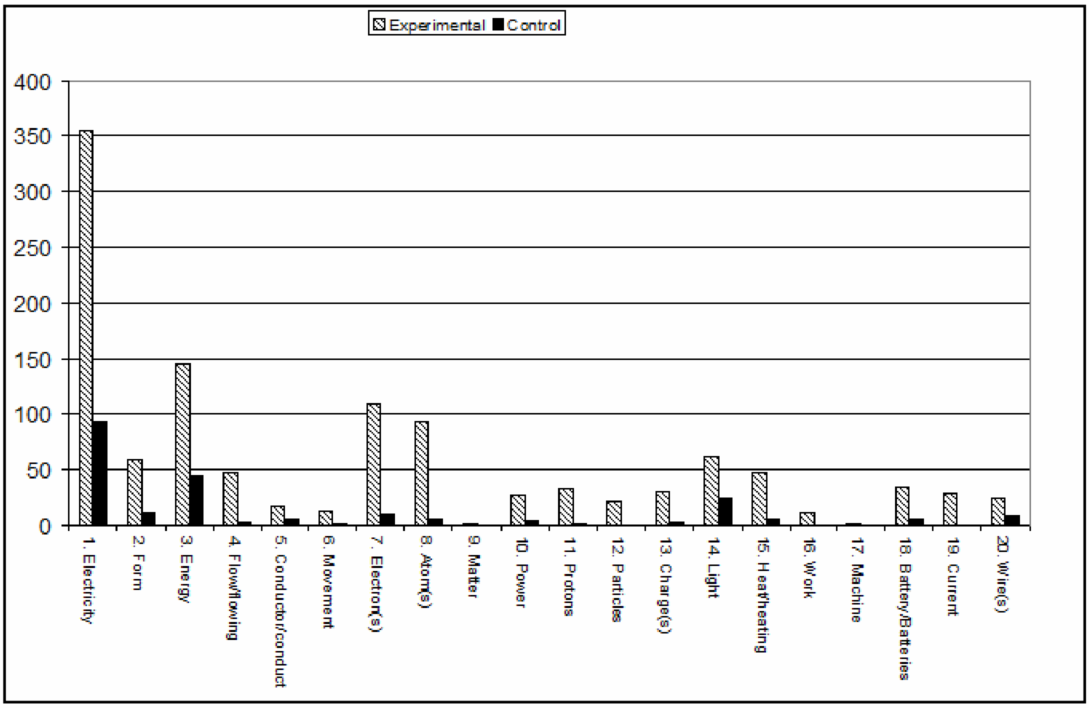


Figure 15: Lexical-conceptual profile of experimental and control group



4.8. Student made pictures (common patterns in both groups)

Students in both groups were also encouraged to draw pictures to reflect their understanding of the word electricity. All pictures were classified based on some commonly observed patterns. The classification of the picture groups is comprised of eight categories: functions of a simple circuit, examples of static electricity, differentiation between AC and DC, the generation of electricity, bulb, battery, conductors and insulators, and others (Appendices 4, 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, 4I). Students in the control group made significantly less number of pictures as compare to the experimental group. Also, students from the control group have drawn pictures that come only under the classification of ‘functions of a simple circuit (battery, bulb, wires). The experimental group of Canada has made significantly higher number of pictures (Table 17). The highest number of picture category found in the Canadian experimental group is ‘structure of atom’ (65%), followed by ‘functions of a simple circuit’ (23.33%), ‘generation of electricity’ (15%), ‘examples of static electricity’ (13.33%), ‘others’ (10%), ‘battery’ (5%). Some other groups are in less than 5% such as: ‘AC and DC classifications,’ ‘bulb,’ and ‘conductors and insulators.’ This comparison shows a significant number of students in the experimental group have reflected their understanding using the picture of ‘structure of atom’ and ‘simple circuits.’ It is significant that students in the control group have made less total pictures, also noting that they have not made even one picture about the structure atom.

It is very clearly notable (Table 17) that students in the experimental group have used many more pictures (48 students made pictures) to support their ideas with pictures than in the control group (only 2 students have made pictures). Students in the Canadian experimental group show (Table 16) the pictures of electrons and atoms to provide a more explanatory process for electricity as compared to students in the control group (Appendix 4A to 4J) who only draw about the use of electricity in daily life. This result gives some evidence to find the effect of different resources used in the experimental group. The significance of these results also reinforces to use more explanatory understanding tools through textbooks and classroom instruction.

More research is needed to explore the effectiveness of explanatory understanding through various methods and resources. A full-scale concept related study on children learning is beyond the scope of this study.

Table 17: Types of pictures in the experimental and control group

Type of Pictures	Experimental Group, n=60 (number of students made pictures)	Control Group, n=60 (number of students made pictures)
Functions of a simple circuit (battery, bulb, wires)	14 (23.3 %)	2 or (3.3 %)
Examples of static electricity	8 (13.3%)	0
Structure of an atom	39 (65%)	0
Differentiate between AC and DC	1 (1.7%)	0
Generation of electricity (turbine, generator etc)	9 (15%)	0
Bulb	2 (3.3%)	0
Battery	3 (5%)	0
Conductors and insulators	1 (1.7%)	0
Others	6 (10%)	0

4.9. Study from Pakistan, content analysis and student responses

The following section presents data from Pakistan on textbook content analysis and student responses. The textbook PT The title is: Science 6, topic Electricity, page 155 to 173. There were 60 students in each group of Grade 6 in the experimental and control group from an urban school, in Pakistan, where all students were male. Some details of the research design are given under the sub-heading 3.1. The Table 18 shows sentences which provide no reason are in large number (91%) as compared to the sentences which provide some type of reason (9%). This trend is also very close to the pattern found in the Canadian textbook.

Table 18: Classification of textbook sentences in two categories (Textbook from Pakistan)

No.	Type of sentences	Count	Percentage
1	Sentences provide no reason (WR)	193	91%
2	Sentences provide a reason (R)	19	9%

In order to enhance the stability of the data, three coders analyzed the data and their analysis has close patterns of concordance.

<u>Coders Responses on Sentence Analysis</u>

● Teacher A [coder 1]: Results are given in Table 17 and more details are given in the appendices.

● Teacher B [coder 2]: Results were all the same as coder A, only in sentences 74, it was the opposite to coder A.
● Teacher C [coder 3]: Results were all the same as coder A, only in sentences 98 and 161 it was the opposite to coder A.

As a general comparison this shows a high level of close occurrence patterns in the analysis of three coders.

The Table 19 shows the pattern of occurrence of certain lexemes in the textbook PT about the topic of electricity. The size of textbook CT was bigger than the textbook PT. It is noted that the textbook PK had the occurrence of word "electron" 12 times in comparison to the textbook CT which had zero count of this word. The word "electromagnetic" appeared 4 times in PT as compared to zero in CT. The word "current" was found 39 times in PT and this word appeared only 3 times in CT. The word "charge" was found 8 times in PT as compared to zero time in CT. The word "atom" was not found in PT or CT. This pattern of lexemes occurrence can be compared in terms of how the scientific way of explanation of the concept of electricity is connected with textual formats. The scientific reasoning needs some textual connection with the lexemes "electrons" (and their flow), the role of "charge" and "current" (in relation to electricity). If those words are found with zero frequency, the scientific explanatory aspect is less emphasized. Those conceptual lexeme profiles indicate one dimension of improving textbooks for scientific reasoning and explanation.

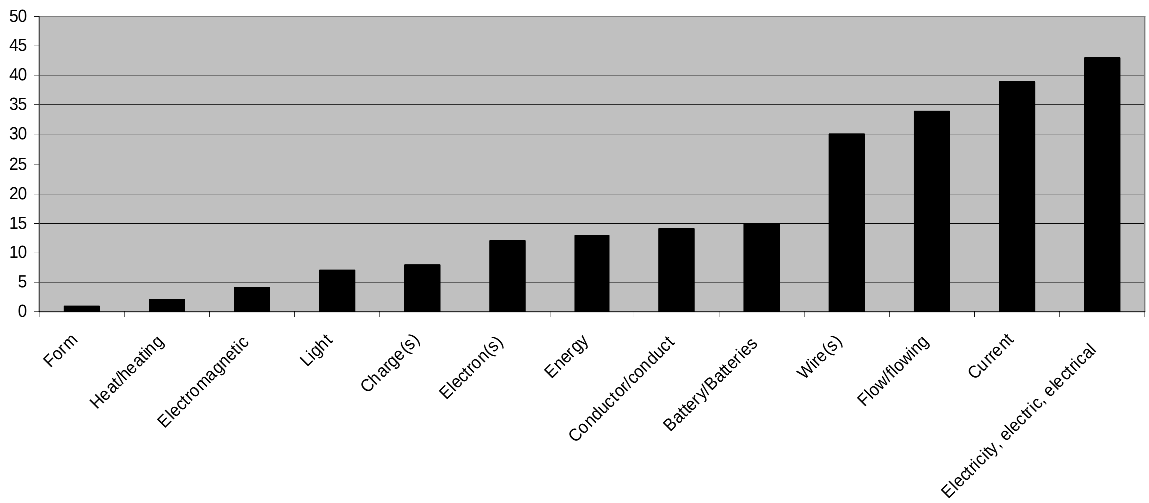
Table 19: Lexical conceptual profile from the textbook (from Pakistan)
(From the textbook), 2748 total words

Keywords	Word Count	Relative Frequency 2748	Relative Frequency (out of 222 words used)
1. Movement	0	0	0
2. Atom(s)	0	0	0
3. Matter	0	0	0
4. Radiation	0	0	0
5. Power	0	0	0
6. Physical	0	0	0
7. Protons	0	0	0
8. Attraction	0	0	0
9. Particles	0	0	0
10. Repulsion	0	0	0
11. Work	0	0	0

12. Machine	0	0	0
13. Form	1	0.04%	0.4%
14. Heat/heating	2	0.07	0.9
15. Electromagnetic	4	0.1	1.8
16. Light	7	0.2	3.1
17. Charge(s)	8	0. 3	3.6
18. Electron(s)	12	0.4	5.4
19. Energy	13	0. 5	5.8
20.Conductor/conduct	14	0.5	6.3
21. Battery/Batteries	15	0.5	6.7
22. Wire(s)	30	1.0	13.5
23. Flow/flowing	34	1.2	15.3
24. Current	39	1.4	17.6
25.Electricity, electric, electrical	43	1. 5	19.3

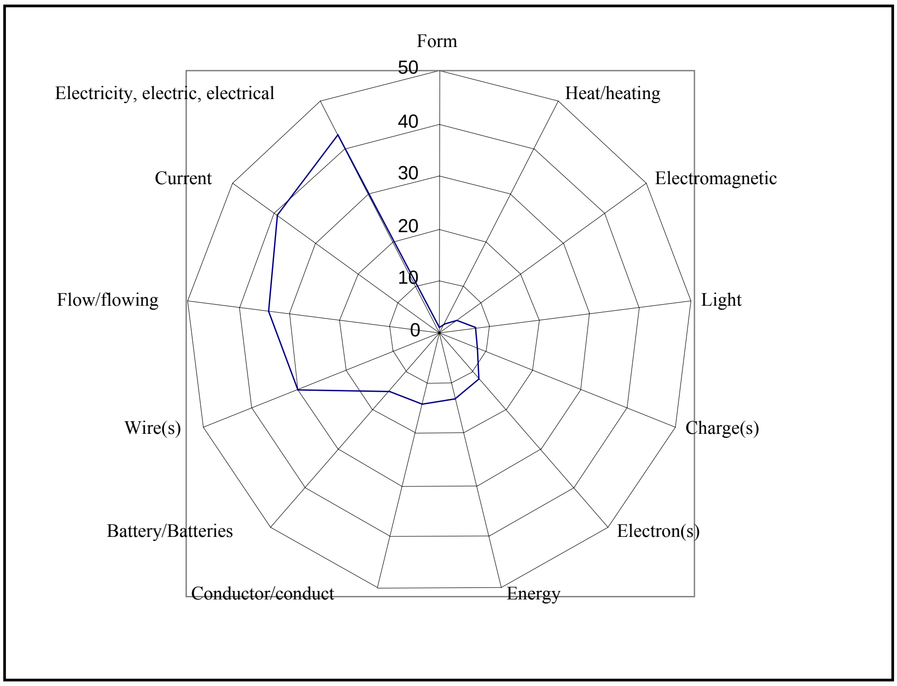
The Figure 16 shows the patterns of lexeme occurrence in the form of a bar graph. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 19.

Figure 16: Lexical conceptual profile from the textbook (from Pakistan)



The Figure 17 shows the patterns of lexeme occurrence in the form of a radar graph. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 19.

Figure 17: Lexical conceptual profile from the textbook (PT) radar graph (from Pakistan)



The Figure 17 shows the key-words frequency occurred in the textbook of Pakistan in a radar graph. The highest frequency is related to word "electric." The key-word "proton" has no occurrence. Some notable contrasts with the CT include, the relative frequency of the key-word "flow" is 15.3 in the PT while this is 0.54 in the CT. The key-word "electron" has relative frequency of 5.4 in PT, which is zero in the CT. The key-word "light" was found much higher in the CT (13) as compared to PT (3).

The results of paragraph analysis for the textbook PT are shown in the Table 20 and 21.

Table 20: Paragraph analysis (27 paragraphs in total)

(1) discusses daily life use of electricity, electricity resources; (2) asks readers to 'think about', ' imagine', 'don't you think', asks questions, asks to identify, asks to compare; (3) explains something using reason(s); (4) Includes numeric values (2 km, 1000 kWh, 1888 AD)

No.	Content Category	Count	Percentage
1	1	12	44%
2	2	10	37%
3	3	9	33%
4	4	1	3.7%

In order to enhance of stability of the data three coders analyzed the data on their own. Coders' responses on paragraph analysis indicate the following results.

● Teacher A [coder 1]: Results are given in Table 20 and more details are given in the appendices.

● Teacher B [coder 2]: Results were all the same as for Coder 1, only in paragraph 2 it was category 3.

● Teacher C [coder 3]: Results were all the same as for Coder 1 only in the paragraph 4 it was category 1, and 3.

Table 21: Paragraph overlap of categories

No.	Overlap	Count	Percentage
1	1,2	2	7.4%
2	2,3	1	3.7%
3	4,2	1	3.7%
4	1,3	1	3.7%

As a general comparison this shows a high level of close occurrence patterns in the analysis of three coders.

The paragraph analysis in Table 20 on the textbook from Pakistan shows the category 1 has 44% occurrence which is the highest among the three categories. The paragraphs related to "think about" and "question asking" is 37%. The paragraphs related to providing some type of reasons in the category 3 have 33% occurrence. This pattern also shows fewer paragraphs about the use of explaining reasons. The trends of paragraphs in the Canadian and Pakistani textbook have a very close frequency for the category 1. In the category 1, Pakistani textbooks have 44% while the Canadian textbooks have 44.57%. This category refers to the use of words about electricity and its uses. The second category has Canadian textbook at 39.75% while the Pakistani textbook at 37%. In "think about" category the trend is not too different. The contrasting one is category 3, in which CT has 8.43% occurrence while the PT has 33% occurrence. The fourth category with numeric values in the text has higher percentage value in the CT as compared to the PT; however, the size of the text has to be taken into consideration. For the theme "electricity" in the CT paragraphs analyzed were 83 while in the PT the chapter on "electricity" has 27 paragraphs. The details of the additional resources used apart from the textbooks CT and PT are given under the sub-heading 3.7 and 3.7.1.

A multiple choice test was given to the Grade 6 students in the experimental and control group (n=60) of Pakistan. It is the same test that was given to the students in Canada. The test was conducted at the end of six week teaching unit on electricity. The Table 22 shows the statistical comparison of the experimental and control group from the study conducted in Pakistan.

Table 22: Multiple Choice Test, Student Responses n=60 (Experimental and Control Group, from Pakistan)

Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Correct Responses (Experimental Group) n=60	57	51	47	28	50	40	41	35	51	43	36	32	40	28	27	50	40	35	34
Correct Responses (Control Group) n=60	50	17	21	26	49	39	29	33	39	41	30	30	19	26	25	31	23	28	23

A common multiple choice test was given to both groups of students from Pakistan (experimental, n=60; and control, n=60) to show what they understand about the concepts analyzed. Hypothesis testing for the mean difference between experimental and control group scores using t-Test:

μ_E = Hypothesized mean for Experimental Group
μ_C = Hypothesized mean for Control Group

The null hypothesis, H_0, and the alternative hypothesis, H_1, are given as follows:

H_0: $\mu_E \leq \mu_C$
H_1: $\mu_E > \mu_C$

Choosing a significance level, $\alpha = 0.05$.

The Table 23 shows the summarized data.

Table 23: Mean of multiple choice test (from Pakistan)

	Mean	Size
Experiment	12.73	60
Control	9.63	60

To test if the two groups are statistically significant or not, we first need to test the equality of the two population variances. Let σ_c and σ_E represent the standard deviation of the control group and experiment group, respectively. The hypothesis is stated as

$$H_0: \sigma_c = \sigma_E; \quad H_\alpha: \sigma_c \neq \sigma_E$$

The Excel output is copied below (This table is copied from the spreadsheet "Step1-TestVariance"). Since the p-value is 0.43 and it is greater than the significance level

0.05. We fail to reject the null hypothesis which assumes equal variances of the two groups. The sample of variance is shown in the Table 24.

Table 24: Two Sample for variances (from Pakistan)

F-Test Two-Sample for Variances		
	Control	*Experiment*
Mean	9.633333333	12.73333
Variance	4.100564972	4.300565
Observations	60	60
df	59	59
F	0.953494482	
P(F<=f) one-tail	0.427747214	
F Critical one-tail	0.649368947	

Therefore, using Excel's data analysis for independent t-Tests assuming equal variances, we obtain the following (Table 25):

Table 25: t-Test for multiple choice test (experimental and control group)

t-Test: Two-Sample Assuming Equal Variances	Experiment	Control
Mean	12.73	9.63
Variance	4.3	4.1
Observations	60	60

Table 26: Pooled variance for multiple choice tests

Pooled Variance	4.2
Hypothesized Mean Difference	0
df	118
t Stat	-8.284541312
P(T<=t) one-tail	1.06633E-13
t Critical one-tail	1.657869522

From the Table 26 it is observed that, since the p-value = 1.07×10^{-13} (that is 0.00000000000107) is far less than 0.05, we reject the null hypothesis. There is sufficient evidence to conclude that the mean of the experimental group is larger than that of the control group.

4.10. Lexical-conceptual profile based on students' writing in both groups (from Pakistan)

As it was also conducted in the Canadian study, the same process was used in the study from Pakistan to explore the students' writing responses and compare the lexical-conceptual profile. The data shows the same 25 keyword occurrence frequencies. In the study from Pakistan, students (n=60 in each group) were not given a formal task to write in the three stages: pre-writing, writing, and post writing. On the same way as in the Canadian study, students were given an open choice to write about their understanding of the term "electricity." In this writing process, students were encouraged to think about the following: the purpose, the audience, their personal understanding of the term electricity, grouping their ideas, and reflect those aspects in their writing.

Students were given the multiple choice test before the writing task that may have given some direction to think about the concepts related to electricity. Some guiding questions before the writing process were related to the students. They were asked to think about who would read this work, and how their ideas could be grouped. The lexical-conceptual profile also explains to some extent the pattern of the use of certain type of keywords by the experimental and control group. As shown in the Table 26 and 27, the experimental group has used more keywords related to atoms and electrons, while the control group has used keywords related to the everyday use of electricity.

4.11. Lexical-conceptual profile (Experimental group from Pakistan)

Student writing patterns in the experimental and control group of Pakistan shows some changing patterns of lexeme use, as shown in the Table 27. The use of word "electron" in the control group was 2 which increased to 89 in the experimental group. The use of word "atom" increased from 1 to 10 in the experimental group. The use of word "current" increased from zero to 9. Those increase patterns were also observed in the study from Canada. Those lexeme indicators are one type of enrichment factor in the students' writing and other aspects can also be compared.

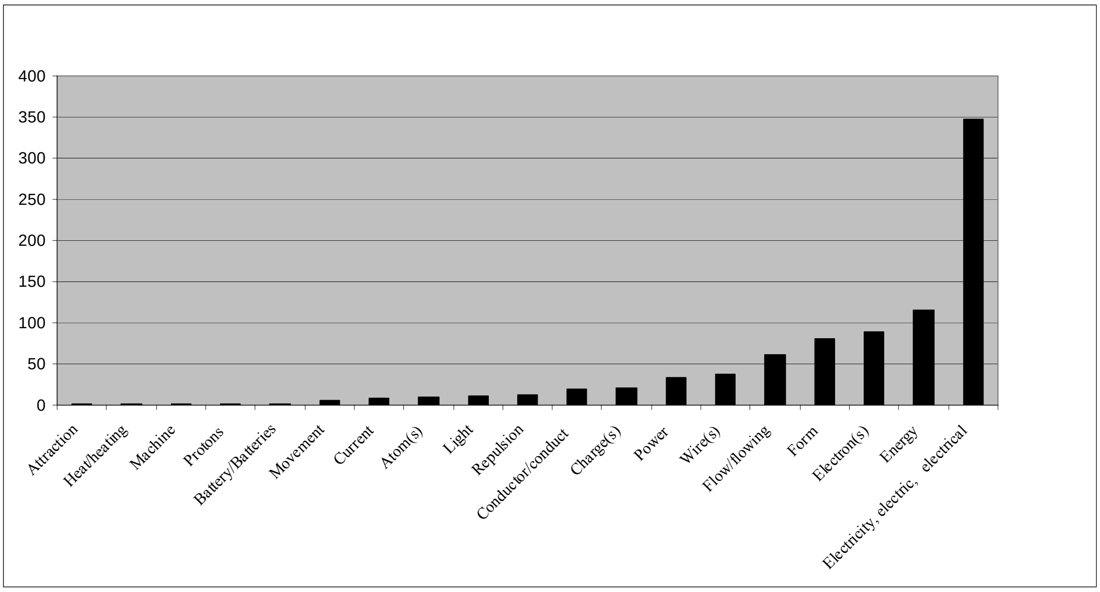
The zero frequencies are not included in the bar graph and the radar graph. Those frequencies can be compared in the Table 27.

The Figure 18 shows the patterns of lexeme occurrence in the form of a bar graph. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 27.

Table 27: Lexical conceptual profile based on students' writing, experimental group from Pakistan (n=60)

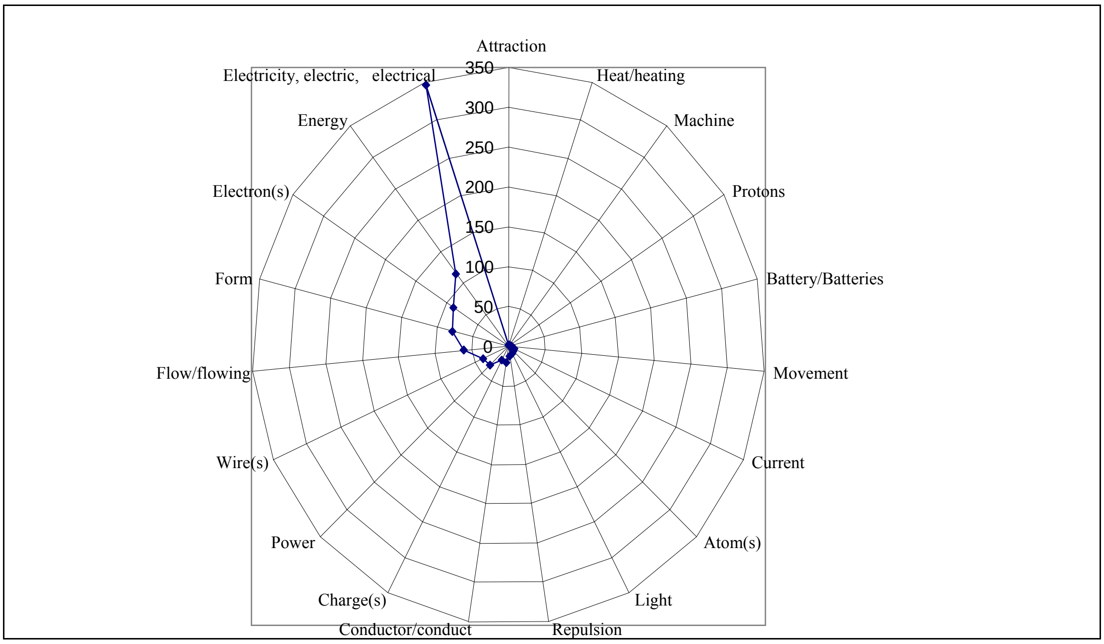
Lexical conceptual profile (From students' writing)			
Keywords	**Word Frequency**	**Relative Frequency(out of 5292)**	**Relative Frequency (out of 858 words used)**
1. Matter	0	0	0
2. Radiation	0	0	0
3. Electromagnetic	0	0	0
4. Physical	0	0	0
5. Particles	0	0	0
6. Work	0	0	0
7. Attraction	1	0.01	0.11
8. Heat/heating	1	0.01	0.11
9. Machine	1	0.01	0.11
10. Protons	2	0.03	0.23
11. Battery/Batteries	2	0.03	0.23
12. Movement	5	0.09	0.58
13. Current	9	0.17	1.04
14. Atom(s)	10	0.18	1.16
15. Light	11	0.20	1.28
16. Repulsion	12	0.22	1.39
17. Conductor/conduct	20	0.37	2.33
18. Charge(s)	21	0.39	2.44
19. Power	34	0.64	3.96
20. Wire(s)	37	0.69	4.31
21. Flow/flowing	61	1.15	7.1
22. Form	80	1.51	9.32
23. Electron(s)	89	1.68	10.37
24. Energy	115	2.17	13.40
25.Electricity, electric, electrical	347	6.5	40.44

Figure 18: Lexical conceptual profile based on students' writing, experimental group from Pakistan (Bar graph)



The Figure 19 shows the patterns of lexeme occurrence in the form of a radar graph. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 26.

Figure 19: Lexical conceptual profile based on students' writing, experimental group from Pakistan (Radar graph)



4.12. Lexical-conceptual profile (Control group from Pakistan)

The Table 28 shows, the appearance of words in the writing of students in the control group from Pakistan. Since this group only used the textbook PT in the conventional way therefore, overall use of lexemes is in sparse numbers. Despite the textbook PT is written in English language, however in that school setting, teachers also used local language to explain the topics of the textbook. The student writing also included some statements in the local language (Urdu) which were translated for the purpose of this study. There are 16 words which are in zero frequency. The use of word “electricity” is in the highest numbers (299) as compared to all other lexemes.

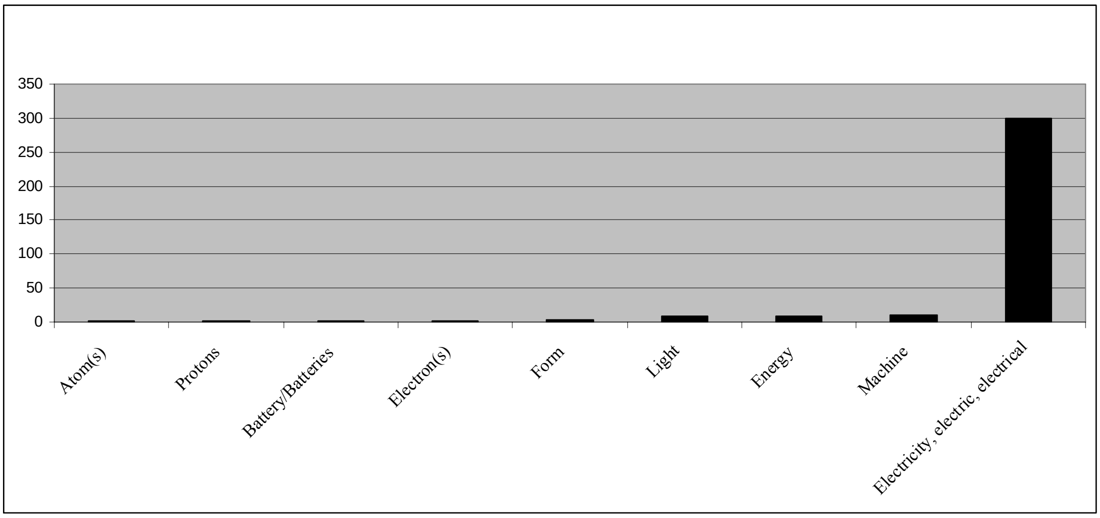
Table 28: Lexical conceptual profile based on students’ writing control group from Pakistan (n=60)

Lexical conceptual profile (From students’ writing)			
Keywords	**Word Frequency**	**Relative Frequency(out of 3623)**	**Relative Frequency (out of 334 words used)**
1. Flow/flowing	0	0	0
2. Conductor/conduct	0	0	0
3. Movement	0	0	0
4. Matter	0	0	0
5. Radiation	0	0	0
6. Electromagnetic	0	0	0
7. Power	0	0	0
8. Physical	0	0	0
9. Attraction	0	0	0
10. Particles	0	0	0
11. Charge(s)	0	0	0
12. Repulsion	0	0	0
13. Heat/heating	0	0	0
14. Work	0	0	0
15. Current	0	0	0
16. Wire(s)	0	0	0
17. Atom(s)	1	0.03	0.3
18. Protons	1	0.03	0.3
19. Battery/Batteries	1	0.03	0.29
20. Electron(s)	2	0.05	0.6
21. Form	3	0.08	0.9
22. Light	8	8	8

23. Energy	9	0.29	2.7
24. Machine	10	0.3	2.99
25.Electricity, electric, electrical	299	8.2	89.5

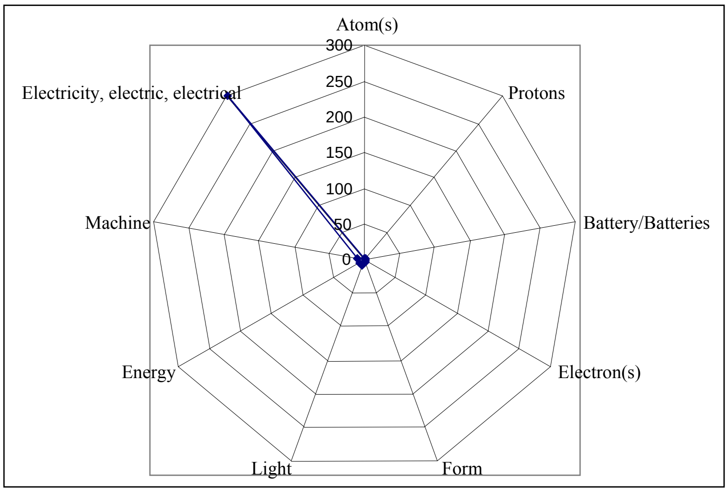
The Figure 20 shows the patterns of lexeme occurrence in the form of a bar graph for control group from Pakistan. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 28.

Figure 20: Lexical conceptual profile based on students' writing control group from Pakistan (Bar graph)



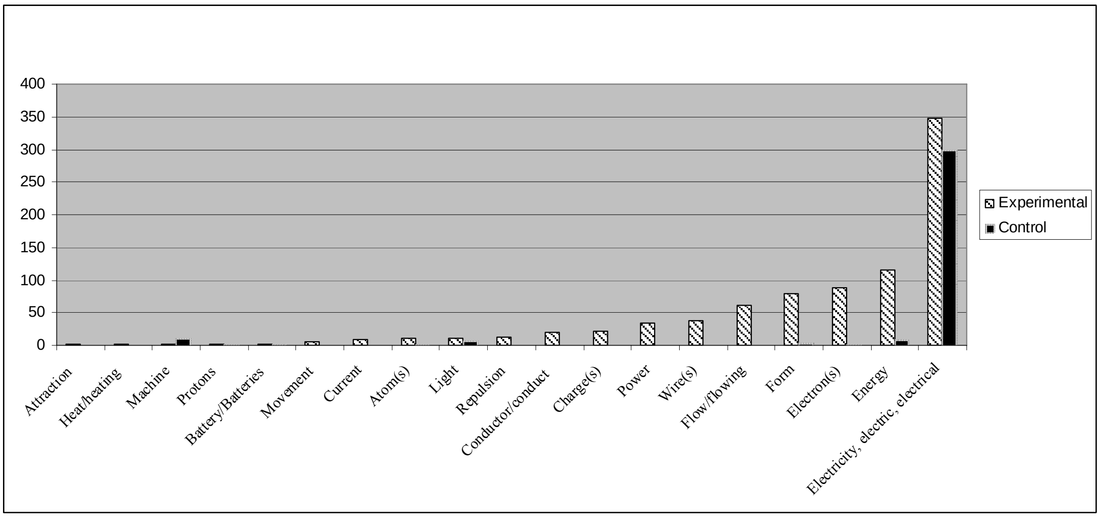
The Figure 21 shows the patterns of lexeme occurrence in the form of a radar graph for control group from Pakistan. The word appeared with zero frequency are not included in this graph. Those words are shown in the Table 28.

Figure 21: Lexical conceptual profile based on students' writing control group from Pakistan (Radar graph)



The Figure 22 shows the patterns of lexeme occurrence in the form of a bar graph for the experimental and control group from Pakistan. The word appeared with zero frequency are not included in this bar graph. Those words are shown in the Table 27 and Table 28. It is clearly evident that experimental group has higher number of lexemes for all word groups.

Figure 22: Lexical-conceptual profile of experimental and control group from Pakistan (Bar graph)



It was noted that out of n=60 in the control group, only 2 students wrote their responses in English, one student wrote in English and Urdu (local language), and 57 students wrote their responses in Urdu language. In the experimental group the language pattern of student response shows, 10 students wrote in Urdu, 41 students wrote in Urdu and English, while 9 students responded in English. Perhaps one possible reason is the exposure to the additional resources use provided from Canada which was used during the study of this unit. This was a Government school in Punjab, Pakistan or a public school compared to Canada. As common in the local tradition it was a boy’s school in Pakistan and female students were not in that class. It was difficult to find a school which has similar parameters as school in Canada. Although students were taught using a Grade 6 science textbook written in English language, however a vast majority of students could not write in English and the majority preferred to write in Urdu language (which was translated in English for the purpose of comparison of key-words and understanding overall comparison). Many students mentioned about their concern about the lack of availability of electricity and the hardship it causes to them. Students in the experimental group were provided with some additional resources, same as used in Canada, and there were some notable changes in the keyword frequency of certain words. The keyword “electron” frequency occurrence was increased to 89 (experimental group) from 2 (control group).

Also keyword “form” frequency moved higher in the experimental group, from 3 to 80, keyword “flow” frequency reached 61 from 0. Overall students in the experimental group of Pakistan have improved in their multiple choice test results and the frequency occurrence of certain words linked to some explanatory terms of electricity. The pattern of those increases is also observed in the student writing responses from Canada. It was also observed that the textbook of Pakistan compared used more atom / electrons related concepts than the textbook compared from Canada. This pattern also relates to the importance of including certain type of atom related concepts in the elementary level science curriculum, as explained by Harrison and Treagust 1996 and Justi and Gilbert 2000. This is an important need for making some improvement in the science curriculum/ textbooks in some parts of the world. Scientific reasoning (explanatory understanding) needs to go beyond the use of electricity in daily life and the concept of electrons plays an important role in this regard.

4.13. Student made pictures from Pakistan

The number of students who made pictures to explain their text was in very small percentage in both groups. In the experimental group from Pakistan only 3.33% students made pictures (of an atom) along with their text, while in the control group 1.66% students made pictures (Table 29). Students were given the option to draw pictures to explain their contents of the text. So it was not mandatory to draw pictures. It was observed that students in this school did not use pictures very commonly to write in their science texts. Perhaps this could be a reason for giving response primarily with more text and less pictures. The textbook PT (relevant chapters) had one chart, 8 circuit diagrams, and 5 other pictures to explain the text given in the book. There was no diagram in the textbook PT to explain the concept of electron flow.

Table 29: Types of pictures in the experimental and control group (From Pakistan)

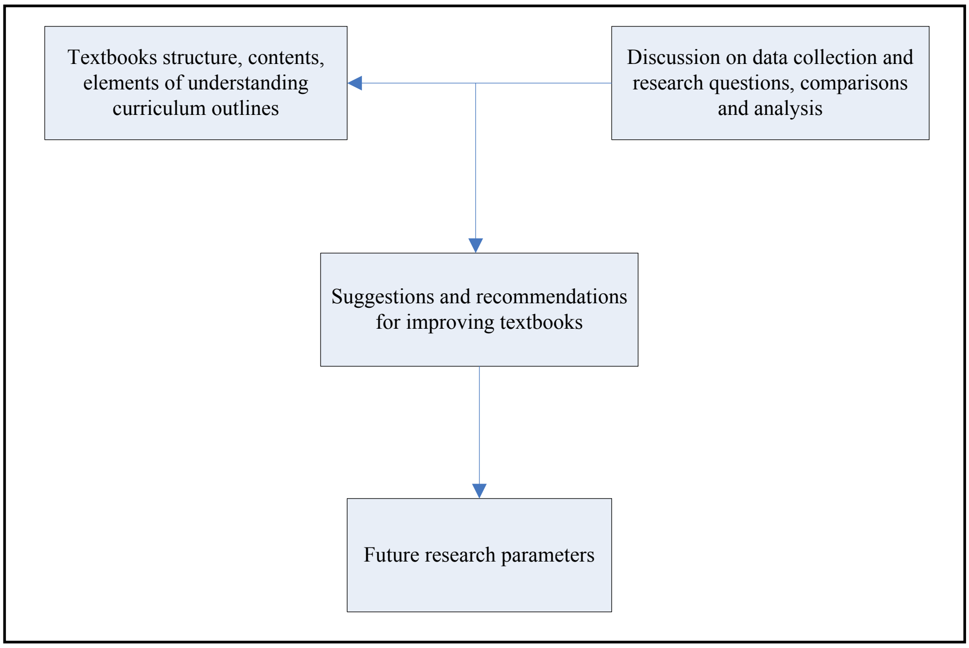
Type of Pictures	Experimental Group, n=60 (number of students made pictures)	Control Group, n=60 (number of students made pictures)
Structure of an atom	2 or (3.33%)	1 or (1.66%)

In the context of data collected from Pakistan, the need to explain scientific concepts can be supported with illustrations of various types. The analysis of illustrations in the science textbooks of Pakistan is a topic which needs further studies. One of the growing areas of illustration analysis is the use of concept specific explanatory illustrations as compared to the simple pictures from the everyday use. The effective use of concept oriented illustrations with scientific reasoning in contrast to the use of pictures which refer to daily life use of certain items has to be compared in the text and illustrations. The use of illustrations is growing in the science textbooks while the pedagogical need is to compare the effective use of illustrations (cf. Lee 2010; Mayer 1993) from the lenses of theory, research and practice.

Chapter 5 ANALYSIS AND DISCUSSION

The data collected for the textbook analysis of CT and PT is comprised of the following frameworks: structure and contents of the CT and PT, comparison of data collected with the research questions, student responses from Canada and Pakistan, pathways for improving textbooks, suggestions for future research. The comparison of the data with interrelated relationships to other frameworks is given below.

Figure 23: Data, suggestions and future research parameters



5.1. The physical structure of the science textbooks analyzed

The textbook on electricity (published in 1999 by Addison Wesley, Pearson Education Canada) was also mentioned on the website of the Ministry of Education, Ontario Canada around those years of publication. The website link was given is as follows:
http://www.curriculum.org/occ/trillium/resources/grade6.shtml#Science%20and%20Technology.

At that time, this website also included a note: "This textbook supports *The Ontario Curriculum, Grades 1-8: Science and Technology, 1998.*" And with changes in the curriculum the textbooks recommended has also changed with time.

The science textbook analyzed CT has the following physical descriptions. The book size is 27.5 cm by 21.7 cm. The textbook has 13 chapters spread over 44 pages. Various types of pictures are given on 37 pages. Images are in black and white and colour with a variety of circuit diagrams and pictures. The glossary is comprised of one page. There is a self-evaluation sheet for students on page 41 of the text, where students rank their work by giving one to four stars. The text uses various patterns of writing according to the context, including matrix, and topical net.

The textbook PT has just one chapter on "electricity" and the other one is on "electromagnet". Both of them in total are comprised of only 19 pages of size 17.5 cm by 22.5 cm. This physical comparison of the textbooks shows the contents of the textbook from Pakistan has a very small amount of textual and pictorial information as compared to the Canadian textbook. This notion is also evident in the data collection aspects.

5.2. The textbook structures, contents, and change recommendations

When the same text and pictures are seen by various readers—especially elementary school level students—the process of in-depth understanding could be highly different from the writers' expectation of conveying the same idea. Due to time and resource shortages, writers cannot always discover how various students will understand each sentence and picture meaning. The creation of effective textbook design is not obtained just by targeting 'meaningful learning,' but it has to inculcate 'correct meaningful learning.' Tapiero and Otero (2002:188) emphasized on the situation models and spatial relations: "spatial relations are excellent examples of the difference between links in situation models and links in textbases. Two objects may be close together or far apart in a reader's representation of a text, depending on the constructed spatial situation model." The study of situation models about the learning of challenging science concepts needs more detailed study in relation to the study of topic of electricity to elementary level students. In this context some important factors with textbook segments from CT and PT are critically discussed.

In the following passages some short quotes (in italics) are given from the 'Electricity' textbook with some discussion for future implications to test students' understanding on these conceptual frameworks and pedagogical concerns. The discussion also raises some questions to explore further on learning from the text and pictures at elementary level.

> *'Electricity. It's all around you. It's invisible.'* (p. 1)

This sentence may not give grade six students a clear idea about how it is all around us. What is the source of electricity in this context? Another concept oriented issue for students is to distinguish between static and current electricity. According to Schlessinger, A (2000) "Electricity: Electromagnetic radiation that is visible to the human eye." (Video: brochure).

It is notable to observe the use of words 'visible' and invisible' by different authors. Perhaps it will be challenging for grade six students to distinguish different perspectives of the authors in this context.

'you will participate in an electric adventure as you learn about electricity.' (p. 1)

What is the meaning of 'electric adventure' here? Perhaps this sentence needs more clarity.

'now you will find out: how electricity is transformed into sound, light and motion' (p. 1)

This question is not really answered in the book. This statement also needs some review and more explanatory sentences to provide reasoning.

Electricity is everywhere (p. 2)

This statement is repeated here and yet not explained. Perhaps students may need a more specific statement to direct their attention.

'If you want to operate a portable radio or walkman, you need batteries' (p. 4)

This statement is true in a general setting, but in more specific terms, other sources may also be workable for this purpose.

'In 1786, while examining a dead frog, he noticed that a spark could make the frog's leg move, when two different metals were touching the frog's leg.' (p. 4)

Which metals are we talking about? Is it referring to any metal? More explanation on how would this happen could be useful.

'As the next lightning storm approached, Galvani used a brass hook to hold the frog's muscle and attached this hook to an iron railing.' (p. 4)

This statement needs more explanation to establish a link between the storm and the hook catching electricity. There is a picture (perhaps hand-drawn) also given in the textbook to show Galvani doing this experiment with a frog. The question for children is if we leave any such metal in the storm, will the electricity reach there or not? If not, then why can it happen only in some cases?

'he could produce a spark' (p. 5)

There is no explanation of how this process took place. How the flow of an electron works in a battery is also not explained in this context. The interpretation of grade six students could be based on highly different experiences of individuals.

'in 1967, then 17-year-old Richard Keefer of Ontario invented a battery that could run on garbage!' (p. 5)

How could garbage generate electricity? This question needs more explanation.

'Where Does Electricity Come From?' (p. 10)

The information provided covers some renewable energy resources. However, the underlying reasoning on the flow of electricity needs more explanation. If students understand the basic process involved in the flow of electricity, perhaps they can make more logical connections to the rotation of a certain wheel to the generation of electricity.

'A renewable energy resource can be used over and over. It is never used up.' (p. 10)

In consideration to the awareness of environmental issues, the statement 'it is never used up' needs more explanation. Perhaps it is an opportunity to integrate learning on science and society.

'it ensures that there will always be water available to run the generators and make electricity.' (p. 11)

On one hand, this book is talking about 'always' and 'renewable,' yet this book also talks about environmental concerns and how we are losing our resources. However, maybe a more balanced approach to explaining or more careful selection of words would be useful.

'A wire is drawn in either a straight line or at a right angle if the wire changes direction.' (p. 17)

In the text it says 'right angle,' but the picture of the wire (not the circuit diagram) does not show a right angle. It is more like a semicircle. A more specific connection between text and picture(s) might facilitate to avoid confusion for younger children.

'the symbol for a light bulb is:' (p. 17)

After this statement, two pictures are given. While the picture of a real bulb is given, it may not be clear for a grade six student which picture shows the symbol. Students' understanding can be tested to facilitate graphic comprehension for further publications. While showing the picture of a switch (on page 18 of the textbook), it is not clear whether students can distinguish between conductor and insulator parts of a switch. Explanatory sentences can support the pictorial presentation of such aspects of invisible processes.

'The photoelectric cell detects light and produces electricity. This type of cell is also used in solar energy.' (p. 18)

The statement 'used in solar energy' may lead to misconception. Is it used in the Sun too? Perhaps more specific application of language can facilitate to explain this concept.

'open switch,' 'closed switch' (p. 19)

The circuit diagram is also given on that page and according to this diagram, the open switch refers to OFF, while the close switch refers to switch ON. Perhaps children may think of 'closed' and 'open' as the analogy of a door. In the 'closed' door, one cannot enter, while the 'open' door allows entrance. This logic is reversed in the context of an electrical switch and circuit diagram. The open switch (words and diagram) means the bulb will be OFF, and the closed switch means the bulb will be ON. This concept needs some clarification to make a connection with the circuit diagram and the previous knowledge of grade six students.

'all circuits can be classified as one of these types' (p. 20)
'if you can place your finger on any part of the circuit and trace a path back to the start, you have a series circuit' (p. 21)

The possibility of tracing back to the start is not a clear distinction as this may also happen in the parallel circuit. Comparing both types side by side with more clarity can be helpful.

'in some situations, electricity does not move. This is called static electricity' (p. 26)

If this statement or situation is compared with an OFF circuit, students might suppose that electricity is not moving in the OFF circuit. How would the notion of 'not moving' relate to the notion of 'static electricity?' Explanatory sentences about the role of electrons and charges can specify more dimensions.

'Magnets can exert a force on an object and make it move without touching it.' (p. 28)

The statement talks about 'an object' and that may lead a student to think of any object, regardless of what it is made of. Can magnets attract *anything* or just *specific* metals? Despite using simple language, the need for more specific language is obvious to reduce the possibility for misconceptions.

'Electrical circuits require a battery, wires, and an electrical device to operate.' (p. 43)

Is it always just those three things? More specific circuit parts have to be mentioned and explained, or a very general statement should be made with some specific parameters (such as inserting words like 'commonly' or 'in general').

The Grade six **textbook from Pakistan**, Punjab Textbook Board, published 2011, has a chapter on electricity. Some sentences from this textbook may also have similar concerns. Some examples include the following.

'We know that nobody moves by itself.' (p.155)

The word 'nobody' may lead to think of human bodies, while the intended meaning may be referring to 'nothing' which includes living and non-living things. The word 'nobody' may cause ambiguity to understand the links to the concept of energy.

'There is abundance of electrons at the negative terminal of the dry cell and much less electrons at the positive terminal. The difference causes the flow of electrons.' (p.155)

The explanatory aspect is missing to explain how this happens. The previous discussion in the textbook does not make a gradual conceptual link to this idea.

'The electric current does not pass equally easily through all conductors. Different amounts of current pass through different conductors.' (p.156)

The sentence does not give any reason why it happens, how it happens.

'Due to loss of energy, the electric charges slow down and the current deceases. The greater the energy is lost, the lesser will be the flow of current.' (p. 156)

In view of how law of conservation of energy is taught, this sentence may not be very clear. If energy can not be lost why this sentence says energy is lost. Perhaps more explanation could be given with the conceptual framework of energy quadriga (energy transformation, energy transportation, energy conservation and energy degradation). The inclusion of this aspect in the textbook of Pakistan can also be useful as the concept of energy is not explained in relation to the energy transformation and energy transportation.

In view of the above discussion, research studies on textbooks can also collaborate with the process of textbook designing and exploring ways to promote explanatory understanding.

The CT has some indication to persuade students to think about how they learn (metacognition). The following examples can be noted.

"*Write a short note explaining how well you think you did it*." (p. 41)
"*Does your work show you know?*" (p. 41)
"*Suggest how you would improve your device next time*." (p. 39)
"*You may have noticed that you and your partner sometimes use different words for the same thing*." (p. 17)

The PT also has some indication of metacognition, for example:

"In the previous class, we have learnt about the electric circuit." (p.155)
"Can you find how many paths are there for the current to flow." (p.160)

The aim of this study, however, is not to explore metacognition trends in the learning of Grade six students. Students were encouraged to think about the questions leading to the concept-related links in their ideas. Perhaps due to this reason, some students involved in the research study have reflected on their own learning process. For example, a student responded in the writing task of this study from Canada as follows :

"*I do not know much about electricity because I am still learning*."

Another student writes: "*In this paragraph I will tell you all about what I understand and know about electricity. It is also my definition. In my mind electricity is the flow of electrons*." One student from Pakistan writes: "*If you want your AC (air conditioner) then unless the wire goes into the board of switch it will not work*."

The above mentioned instances of the textbook and the student responses give a limited format for metacognition awareness. With the support of further research more integrated examples of the metacognition process can be assimilated in the textbooks. Further research analysis can be structured around the narrative inquiry of metacognition, recognizing and analyzing learning pathways of a large scale of population, and finding common errors in the learning process.

5.2.1. Discussion on Ontario curriculum expectations and the contents of the textbooks

The Ontario Science and Technology Curriculum (1998:64-65) has the following expectations (Electricity) for grade six students:

*"**Energy and Control: Grade 6 – Electricity***
Overview
Electricity is a versatile form of energy that students encounter every day. Although students will already know about many of the uses of this convenient source of energy, they need to develop a deeper understanding of how it can be used to send signals. It

is important for students to learn about this specialized area of study called electronics, which has made a major impact on our lives through many products and devices. Building on previous learning, students will explore devices that use tiny electric currents to switch electric circuits on and off, in order to understand how electronic systems are able to control very complicated processes automatically. As students expand their knowledge of the significant role electricity has in their lives, they should strengthen their awareness that they have control over the amount of electricity they use in the home and at school, as well as their awareness of the potential impact of the over-consumption of energy on our electricity supply.
Overall Expectations
By the end of Grade 6, students will:
** demonstrate understanding that electrical energy can be transformed into other forms of energy;*
** design and construct a variety of electrical circuits and investigate ways in which electrical energy is transformed into other forms of energy;*
** identify uses of electricity in the home and community and evaluate the impact of these uses on both our quality of life and the environment.*
Specific Expectations
Understanding Basic Concepts
By the end of Grade 6, students will:
** investigate ways in which electrical energy can be transformed into other forms of energy (e.g., into light, heat, and sound);*
** compare the conductivity of a variety of solids and liquids;*
** identify, through experimentation, ways in which chemical energy can be transformed into electrical energy (e.g., build a circuit using a lemon or a potato);*
** compare the characteristics of current and static electricity;*
** describe the relationship between electricity and magnetism in an electromagnetic device;*
** identify, through observation, the effects of using different types of core materials in building an electromagnet;*
** identify different types of switches that are used to control electrical devices (e.g., contact, tilt) and explain the key differences among them (e.g., differences in design, use).*
Developing Skills of Inquiry, Design, and Communication
By the end of Grade 6, students will:
** formulate questions about and identify needs and problems related to the properties or uses of electrical energy, and explore possible answers and solutions (e.g., compare some sources of electrical energy used in the past, such as coal, with sources used today, such as uranium and moving water, and evaluate the advantages and disadvantages of each);*
** plan investigations for some of these answers and solutions, identifying variables that need to be held constant to ensure a fair test and identifying criteria for assessing solutions;*
** use appropriate vocabulary, including correct science and technology terminology, in describing their investigations and observations (e.g., use terms such as current, battery, circuit, conductor, insulator; positive (plus) and negative (minus) charges for electrically charged materials; north pole and south pole for magnetic materials);*
** compile data gathered through investigation in order to record and present results, using tally charts, tables, labelled graphs, and scatter plots produced by hand or with a computer (e.g., record in a journal all daily uses of electrical energy for a week,*

classify the various uses, and present the findings using tables and graphs);
** communicate the procedures and results of investigations for specific purposes and to specific audiences, using media works, oral presentations, written notes and descriptions, drawings, and charts (e.g., draw a diagram of an electrical circuit using appropriate symbols; create a brochure outlining safe and unsafe uses of electricity; create a table showing different factors that could lead to a decrease in consumption of electrical energy in the home and at school);*
** design and build electrical circuits (e.g., series circuits and parallel circuits) and describe the function of their component parts (e.g., switches, power source);*
** build and test an electrical circuit that performs a useful function, and draw a diagram of it using appropriate electrical symbols;*
** construct series circuits (e.g., logical AND) and parallel circuits (e.g., logical OR) to control a device, and compare their characteristics;*
** design and construct an electrical system that operates a device in a controlled way (e.g., a switch provides a controlled input, and lamps, buzzers, or motors produce the output).*
Relating Science and Technology to the World Outside the School
By the end of Grade 6, students will:
** identify sources of electricity and state whether the sources are renewable or non-renewable;*
** recognize the use of electromagnets in motors and generators;*
** describe the electrical conversions in everyday devices or systems (e.g., electrical energy to heat energy in a toaster; electrical energy to mechanical energy in an electric mixer);*
** identify the different ways electricity is produced (e.g., by batteries using chemical energy; by dams using water power; by generating stations using nuclear energy) and evaluate the effect of different production methods on natural resources and living things in the environment;*
** describe conditions that could affect the consumption of electrical energy in the home and at school (e.g., seasonal variations in heat and light requirements);*
** identify devices that use electricity to send signals (e.g., televisions, telephones, radios, computers);*
** describe how electricity was discovered and harnessed for use (e.g., name some inventions) and discuss whether we are more or less dependent on electricity than people in the past;*
** develop a plan for reducing electricity consumption at home or at school, and assess how this change could affect the economy (e.g., jobs) and our use of natural resources."*

The following is a list of contents of the textbook on Electricity, Grade 6:

"Launch: Electricity Is Everywhere….2
1: The Shocking Background to Electricity….4
2: Characteristics of Electricity….6
3: Where Does Electricity Come From?....10
4: Light Up the Class….15
5: Key Features of Electrical Circuits….17
6: Different Needs, Different Circuits….20
7: Fixing Electrical Problems….23

8: A Special Kind of Electricity- Static Electricity….26
9: Learning About Magnets….28
10: Electrical Picker Uppers….30
11: Talking Around the World- Thanks to Canadians….32
12: Electricity-Use it Carefully…..35
13: Conserving Electricity….37
Design Project: Secret Talk….38
Unit Review….40
Glossary….44”
(Campbell et al. 1999: 1)

The outline of the curriculum gives some general parameters, and many variations of delivered curriculum are possible due to the wide range of ‘curriculum expectations.’ The way various educators will interpret and apply those ‘curriculum expectations’ is in itself a topic for research study. A closer look at the ‘content list of the textbook’ and the ‘curriculum expectations’ can show some common topics or learning strands. The challenge of the frontline teacher is to address those ‘curriculum expectations’ in a given time and resources. The textbook on ‘electricity’ gives some information on the uses of electricity, however, the aspect of electronics in not covered with related details as mentioned in the ‘curriculum expectation.’ (A ‘sentence analysis’ for the textbook CT is given in Appendix 3A). The word ‘electronics’ is not included in the glossary of this textbook. The textbook gives a few opportunities to work with circuits, and provides information on some environmental issues. The textbook gives sparse information on the change of forms of energy (light, heat, and electricity) and how those forms are changed. An opportunity is missed to use the text and pictures to explain electrons-related details that can possibly contribute to deeper understanding of the topic (the curriculum expectations can further reinforce it). Observing the use of electricity in daily life and developing an understanding of an atom-related concept of electricity can perhaps facilitate explanatory understanding.

5.2.2. The grade six Ontario science curriculum expectations related to electricity in the context of other elementary grades

The Ontario science curriculum (1998) uses five strands for grades one to eight which includes: life systems; matter and materials; energy and control; structures and mechanisms; earth and space. Among all those strands, the topic of electricity is quoted in other related fields too. The topic of electricity is specific to grade six under the strand energy and control. The analysis shows that the word electricity or its derivative words are mentioned in this context 31 times. It is noted that the conceptual links to the atom-related or electron-related expectations are not specified. The understanding of the atom-related concept can also facilitate the understanding of energy transformation, which is an identified “overall expectation.” If the Ontario science curriculum expectations for grade six are excluded from the “energy and control” strand, the word electricity or its derivatives are mentioned in the following pattern. For grade one it is three times; grade two it is three times; for grade three it is five times; for grade four it is none; for grade five it is two times; for grade seven it is one time; and for grade eight it is two times. This analysis is also similar to the previous one where the atom-related or electron-related concept of electricity is not specified.

In the overview of the grade six Ontario science curriculum (1998:64) expectations, it is stated that:

> Building on previous learning, students will explore devices that use tiny electric currents to switch electric circuits on and off, in order to understand how electronic systems are able to control very complicated processes automatically.

The word "electronics" is not mentioned in any of the grade six Ontario science curriculum expectations (while this word is referred in the overview). Since the number of expectations has a range of topics to cover, the specific use of a term such as electronics or electrons provides information for a clear plan to design the delivered curriculum. The connection between electronics and electrons is reinforced by Issacs (1986: 404) as: "The study of devices that control and utilize the movement of electrons and other charged particles." The explanatory understanding of science is associated with exploring reasons for processes or how certain things work as compared to observing the use of appliances in daily life.

The Ontario science curriculum has another closely associated strand to electricity: "matter and materials." For grade six, this strand has the specific topic: "Properties of air and characteristics of flight." For the previous grade, this strand has the specific topic: "Properties of and changes in matter." In the "specific expectations" for grade six on the topic of electricity it refers to the skills learned in the previous grade. If grade five *overall expectations* for "matter and materials" are compared, they emphasize on the understanding of three states of matter: investigate change in state (such as melting, freezing etc.); making informed choices when designing and constructing objects; and identifying properties of materials in everyday use. Students may experience the changes in the state of matter. However, the underlying connection with atoms provides scientific explanation that can be further developed in the next grades. The concept of atoms can facilitate the learning of other strands of science, such as electricity. This study shows through empirical analysis that grade six students can make some connections to the concept of atoms and electrons with the phenomenon of electricity. The conceptual change process in science and the students' performance has a link with the previous and newly acquired knowledge. According to Chambliss (2001:263):

> Readers neither build new understanding nor change their beliefs readily. A passage that addresses explicitly both what children already know and the

> desirable new understanding may well be more persuasive than a passage that does not meet these criteria.

The outline of the curriculum provides a pathway for developing textbooks and shaping the delivered curriculum. The ideal text is comprised of “right elements and right linkages” (Chambliss and Calfee 1998). If one of them is not matching, the overall text design will not convey the desired meaning. The use of the right term with the right linkage is a common example to show the ideal text design to convey explanatory understanding. The above analysis puts emphasis on the use of clear wording (right elements and right linkages) in designing curriculum expectations so that the delivered curriculum and the curriculum received can also reflect explanatory understanding in some way.

5.2.3. The content variations in the textbooks and the matching of Ontario curriculum expectations

The textbook CT also provides a teacher’s guide and program overview (Alexander et al. 2000) book to support the classroom delivery of the curriculum. On the back cover of the program overview book, Alexander, et al. (2000:49) assert: “Addison Wesley Science and Technology provides a 100% match to the Ontario Science and Technology Curriculum and reflects the Pan-Canadian Common Framework of Science Learning Outcomes.” From a logical standpoint, if this textbook or the textbook guide provides a 100% match to the Ontario science and technology curriculum, then anything missed in the Ontario curriculum would also be left out of those resources. On page five of this program overview, the overall expectation or outcome of the Ontario curriculum is given regarding electricity which says, students will learn: “How electricity is transformed into sound, light, and motion.” Can we explain how electricity transforms into various forms of energy without explaining what happens to the electrons and atoms? What happens with the electrons needs some links with the structure of atoms. Students advancing to the grade six level in Ontario have studied about the structure of atoms in previous grades or preceding strands, and may appear to be the pedagogical barrier to explain the links of electricity and the structure of atoms due to the lack of consistency in the conceptual continuum. As previous analysis and discussion has concluded, the textbook CT provides some contents in the textbook and experiments on various uses of electricity. The way that electricity changes into various forms is not explained in that textbook. For educators, the argument is whether the claim made by the publisher on the 100% match to the curriculum sustains if the textbook does not reflect on scientific reason to explain the process for the transformation of electricity into sound, light, and motion, as mentioned in the Ontario science curriculum (1998). The change of the forms of electricity is also related to the law of the conservation of energy. The Ontario science curriculum (1998:62) has an expectation for grade five students to “describe how energy is stored and transferred in a given device or system (e.g. in an automobile, chemical energy stored in the gasoline is transformed into mechanical energy upon combustion, enabling the vehicle to move and releasing thermal energy as heat).” There are other curriculum expectations which relate to other forms of energy transformations, such as light, electricity, sound, and kinetic. As designed in the curriculum expectation, the question of how it happens leads to the explanatory understanding of this concept. The explanation of energy transformation and energy transportation is also linked to the concept of atom and electron flow. Due to the lack of emphasis on the concept of atoms, the scientific reasoning of energy transformation is not clearly addressed in those textbooks. For example, the grade five textbook “Conservation of Energy” (Campbell, et al. 2000) gives no definition of the term “conservation” in the glossary. This textbook also maintains: “Energy cannot be created or destroyed. It can only be transformed from one form to another.” Campbell et al. (2000:11) further elaborate:

> We can store energy in one form until we need it. Then, we can transform it into other forms that we can use. When you take your lunch to school, you are taking the chemical energy stored in your food. Later, when you eat the food, your body will transform it into forms of energy you need—kinetic energy for movement and thermal energy to keep you warm.

The above explanation raises many questions regarding the concept of energy transformation and energy transportation differentiation. The other abstract ideas related to how it happens are not clarified. Perhaps one possible way is related to linking those ideas to atoms and electrons can be useful, which is also discussed previously in relation to the grade six textbook.

The textbook CT also comes with a teacher’s guide. On page 13 of this guide, the authors refer to the following Ontario Curriculum (1998) expectations as part of the learning focus of chapter 2 in the textbook:

> (1) Investigate ways in which electrical energy can be transformed into other forms of energy.
> (2) Compare the conductivity of a variety of solids and liquids.
> (3) Identify, through experimentation, ways in which chemical energy can be transformed into electrical energy.
> (4) Use appropriate vocabulary, including correct science and technology terminology, in describing their investigations and observations.
> (5) Describe the electrical conversations in everyday devices or systems.

At the end of the corresponding chapter of the textbook CT there is the following question for students to communicate their understanding: “Use the information from the three activities: Create a mind map that represents your understanding of the characteristics of electricity. To help you, start with a central picture representing a situation that uses electricity.” This question does not emphasize on which characteristics of electricity students have to communicate. As a result, chances are that many grade six level students may not reach the core of the question that is trying to align with the curriculum expectation on the change of the forms of electricity. This was also seen in the interactions with the grade six students who used this textbook. Prevalent responses of the students were on the appliances that use electricity, rather than explaining how the flow of electrons works. Since the textbook publisher of the teacher's guide of CT highlights in the beginning of each chapter which curriculum expectations the focus of the lesson is going to be on, the match of the curriculum expectations with the concluding questions of the textbook provides some semantic focus for learning a science concept. The teacher's guide of the textbook Electricity (Campbell et al. 1999:17) provides the following guideline for teachers to look at the students' responses to this question: "You may wish to approach this as a class. A successful mind map may include the following terms: Volta, Galvani, frog, muscle, battery, LED, wire, conductor, insulator, and energy transformations." The question from the perspective of explanatory understanding is how those terms can inculcate the idea of electron flow. The possibility of missing this key idea in student learning is more likely when the focus of the textbook contents, nature of experiments, concluding questions and the teacher's guide are not aiming for it. In the section "build on what you know" the teacher's guide (Armstrong et al. 2000:16) maintains that:

> Students may need to be reminded of the different types of energy transformations they have studied in previous science classes. Examples you may wish to remind them of could include heating water in a kettle (electrical energy transformed to heat and sound energy) or burning a log of fire (chemical energy transformed to light, sound, and heat energy).

If the logical pattern of the textbook is compared with the above statement, the previous lessons do not focus on the change of the forms of electricity. For example, the concluding questions (Campbell et al. 1999:5) in the previous chapter are as follows:

> (1) Imagine life 200 years ago, without electrical devices. Which of these electrical devices would you miss most?
> (2) Describe what a day in your life would be like, if you had no electricity.
> (3) Work with a small group. Read and discuss the following statement: "we are more dependent on electricity than people in the past." Present your ideas to the class.

It is evident from the above questions that they do not concentrate on the change of forms of electricity, therefore it is not clear why it was referred to in the teacher's guide as having been studied prior to grade six. The didactic questions arise, such as how the example of heating water in a kettle would provide a scientific reason for energy transformations from electrical to heat and sound energy. The role of atoms in matter is a crucial component in explaining this idea. The other conceptual barrier is how students can distinguish energy transformation from energy transportation in those examples. The travel of electricity from one point to the other through wires is energy transportation, while the concept of transformation is referred to as the change in forms of energy. The conceptual links also deal with how those two components are related in some ways with reference to atoms. The age of the students plays an important role in making a decision on how far we want to explain those ideas. As compared with the examples given above, some presentation of science ideas is only at the observing daily or common uses of science-related concepts, while the part of scientific reasoning is presented in a very limited way. How far those two aspects can form our teaching, text designing and curriculum guidelines is a matter of ongoing debate for various disciplines.

Chapter two of the textbook has a pedagogical aspect, and provides many opportunities to experiment with simple circuits and the use of various fruits to make LED lights turn on. The textbook Electricity (Campbell et al. 1999:9) provides the following statement: "Energy transformations occur when electrical energy is converted to heat energy, mechanical energy, and chemical energy. Describe examples of energy transformations you observed in the toys." The question is phrased with a previous short description, and then extends thinking with the examples given. As it can be noted, this short description is not enough to explain this concept. The use of analogies and inscriptions has shown effective results to improve explanation (cf. Roth et al. 2005; Chiu and Lee 2005; Roscoe and Mrazek 2005). Instead of making a short statement, as shown above, the textbooks can include effective and empirically tested analogies and inscriptions to support student learning of this concept. At the end of chapter two, the textbook Electricity (Campbell et al. 1999:9) provides another exercise. It asks students to "Complete the sentence: I know electricity can move from one place to another because…" As discussed previously, the concept of energy transformation and energy transportation is not clarified in that textbook, and neither is the concept of electron flow included, therefore students may not be able to provide scientific reasons to describe this question with an explanation.

The Grade seven textbook Science Power 7 (Galbraith et al. 1999:206), describes the law of the conservation of energy as: "Energy cannot be created or destroyed. It can only be transformed from one type to another or passed from one object to another." This description brings many domains together to debate what it means to a scientist, educational linguist, a cognitive scientist, and a frontline teacher. A careful reading of this description of the law of the conservation of energy makes the reader think whether energy transformation and energy transportation can happen simultaneously. The wording appears to state that either energy transformation occurs or energy transportation happens. That concludes that only one—not both—of them can happen at the same time. Conversely speaking, energy transportation and energy transformation can take place at the same time. Imagine a simple circuit as shown in CT (Campbell et al. 1990:19), with a bulb, battery, switch, and wires. Energy transportation is occurring by way of the electricity running from the battery to the wires, switch, and bulb; on the other hand, electricity is changing forms from chemical to light and heat, which is energy transformation. In one simple circuit, energy transformation and energy transportation can happen simultaneously, while the use of word “or” in the description of the textbook Science Power 7 (Galbraith et al. 1999:206) implies that only one of them can happen. Since the law of conservation is not included in the grade six Ontario curriculum and the CT does not explain how electricity changes the forms, there is an evident need to update these resources in order to incorporate explanatory understanding. This discussion shows the need for a logical conceptual continuum, as well as the presentation of information with more clarity from one grade level to the other in curriculum outlines and textbook designing. This argument also shows the need for effectively collaborating interdisciplinary domains when writing textbooks and curriculum outlines.

In relation to the Ontario science curriculum (1998) another textbook is used. In **Science Everywhere 6** (Asselstine et al. 2005), the topic of electricity covered by this book has used the link to electrons in the following way:

> A dry cell or battery changes chemical energy into electrical energy. The electrons produced in it leave the dry cell and travel through one metal wire to the light bulb. The electrons then travel through the light bulb, causing its filament to heat up and glow. From the bulb, the electrons travel back to the dry cell to repeat the cycle. (ibid.:182)

The textbook Science Everywhere 6 (Asselstine et al. 2005) did not provide any text or inscription to explain what electrons are and how they flow to produce an electric current. On the other hand, the textbook CT has not explained the flow of electrons and how this concept is linked to electricity, in order for further connections to be made with the related ideas. The notion of the explanation of science related reasoning to electron flow, along with our observation to link the everyday use of electricity in appliances, is a matter of the intended degree of conceptual depth in the curricular framework. Science teaching and learning has to go beyond the daily observation to facilitate constructive framework (cf. Lord, 1998). It is not thorough enough to only identify the physical use of electricity and ignore the scientific reasoning behind the phenomenon. Another example of the explanation of electron flow is given in a children’s book on electricity by Parker (2005:6-7):

> Everything in the universe, from a speck of dust to massive stars deep in space, is made of tiny pieces called atoms. They are so small, this period contains millions of them. Inside an atom, particles called protons and neutrons clump in a central nucleus and around this whiz yet more particles—electrons. Rubbing a substance can cause electrons to detach from their atoms, ready to “jump” to other atoms. This is static electricity, or electric charge. Billions of electrons all “hopping” steadily from atom to atom, in the same direction, form the flow of energy we call electric current.

Parker (2005) has also provided in this book many inscriptions and small subsections with more details of electron flow. The author’s focus of explanation shows the influence in the content design and genre construction. Perhaps one of the factors for the author of a general book for children on science topics is the freedom to write without following a strictly prescribed curriculum guideline. While the in-depth proof of students' understanding from any explanation using text or inscription has a limitation of analysis in a given population and the learning environment, the previous examples show the multiple view points of authors to make possible connections between the relevant factors. If grade six students are exposed to the concept of electricity without linking to the scientific reasoning in order to keep the text simpler, the implications for oversimplified science have to be considered in text and inscription designs for effective learning. Recent studies have hypothesized that oversimplified versions of scientific reasoning is not helpful for students in real-world reasoning situations (Chinn and Malhotra 2002). "Indeed, when students learn an oversimplified, algorithmic form of scientific reasoning in school, they are likely to reject scientific reasoning as irrelevant to any real-world decision making." (ibid.: 213). The rationale to prefer or not to prefer oversimplified vocabulary to teach science is also discussed by the results of another study by Meyerson, et al. (1991: 427): "The direct findings of this study appear to demonstrate a developmental trend in student ability to correctly associate a particular science vocabulary item with an appropriate science concept." The task of the elementary level science curriculum and textbook designers becomes a challenge to constantly integrate previous knowledge and provide opportunities for learning new concepts. This task is further intensified by the fact that individual learners are at various levels. The textbook Science Everywhere 6 (Asselstine et al. 2005:167) provides the following four questions in the beginning, and asks students to write their response in science journals and compare them at the end of the completion of the learning unit. The questions are as follows:

(1) What do you already know about electricity?
(2) How is electricity produced when there is no falling water?
(3) What can electricity travel in?
(4) What things help keep us safe when we use electricity?

Those questions provide a summary of conceptual framework given in the next pages of the textbook. The logical comparison leads to the same basic question of conceptual clarity regarding what is electricity and how the concept of the flow of electrons can be clearly conveyed to grade six level students. The authors of this textbook have also not shown enough details to highlight the in-depth understanding of the process of electricity, perhaps as a result of following the curriculum guideline too precisely, without extending the explanation wherever necessary. The Ontario curriculum expectations can be understood within a broad range of interpretations by the authors, editors, scientists, educators, students, and other readers. For example, one of the Ontario science curriculum (1998:64) expectations for the grade six level requires students to "compare the conductivity of a variety of solids and liquids" and has a range of interpretations when it comes to pedagogically applying them in the classrooms. The frontline teachers showed many ways of applying one curriculum expectation in a number of ways, which is also possible from the scientific and didactic interpretations of such conceptual domains.

Best et al. (2005:71) discuss the conceptual factors in the learning process as follows:

> Students' knowledge deficits may take the form of preexisting misconceptions based on common knowledge or personal experience, rather than scientific concepts. Understanding scientific phenomena often requires adopting a completely different perspective form that acquired from everyday perceptual experiences.

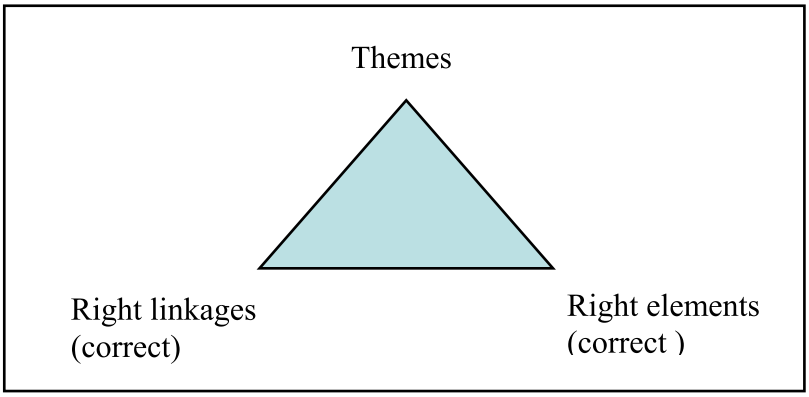
The problem of linking scientific knowledge with the direct experience is making learning accessible, according to the given environment for integrating concrete and abstract nature of the epistemological environment. Best et al. (2005:71) give an example in this regard:

> Children's direct perceptual experience of the movement of the sun in the sky can create the misunderstanding that the sun moves across the sky. This perceptual experience can make it difficult for children to understand that the sun moves as a function of the earth rotating and revolving around the sun, and not the sun's movement around the earth. Children with misconceptions about the movement of the sun may fail to comprehend a text about the solar system accurately because they cannot reconcile information stated in the text with preexisting background knowledge gained from everyday perceptual experiences.

5.3. Deconstructing the textbook design

Chambliss and Calfee (1998) have explained the textbook design in terms of "elements and linkages." Using the example of a bicycle, they have shown a complete and properly-functioning designed bicycle will have correct parts (right elements) with a correctly assembled format using bolts, and a chain (right linkages). In the context of this example, the function of this bicycle design is to help a person move efficiently from one place to the other. The second form is that devoid of a proper design (if the bicycle parts are right but they are assembled incorrectly), the design will not work (right elements but wrong linkages). The third form is that if the wrong parts are used with the correct assembly, the bicycle will still not work (right linkages but wrong elements). Relating this example to the textbook design, the understanding of "elements" and "linkages" is seen as an interrelated function for text designing to facilitate profound understanding (Figure 24 and 25). The elements refer to the theme or specific topic. Various textbooks divide text according to the rationale for connecting the scheme of curriculum, subtopics and comprehension goals. The linkages in the text design refer to the topical frames, including examples, facts, activities, and, graphic presentation of the material. Themes, elements and linkages also relate to comprehensibility, curriculum and, instruction (Chambliss and Calfee 1998).

Figure 24: Textbook designing, adapted from Chambliss and Calfee (1998)



5.3.1. Comparison of the textbooks (CT and PT) design in relation to "linkages and elements" used in the text

In the case of the **Canadian textbook** before the beginning of chapter one, the textbook has cartoons and activities to inspire students to think about "electricity" around them. Chapter one has the heading: "The Shocking Background to Electricity." This chapter has "elements" related to a refrigerator, the use of batteries, the discovery of electricity, the use of an artificial leg or arm, and the early experiments on making a battery. The possible "linkages" include a frog's leg, discovering electricity, making a timeline related to inventors and inventions in electricity, pictures, and activities to compare life without electricity. As the heading shows, this chapter provides a "background" to electricity.

Chapter two has the heading: "Characteristics of Electricity." The chapter contains "elements" related to the making of electricity, the use of switches, and the conductivity of various materials. The possible "linkages" include activities and experiments to make electricity using a lemon, how to differentiate between insulators and conductors, LED uses; there are also pictures of a lemon, an orange, a banana, a switch, a battery, a bulb, circuits and a toy monkey.

Chapter three has the heading: "Where Does Electricity Come From?" The chapter contains "elements" on decision making, renewable and non-renewable energy resources; the advantages and disadvantages of hydroelectricity, solar energy, wind energy, nuclear energy, coal energy; and environment issues. The possible "linkage" include a + and – chart design, pictures of a bicycle, electricity production plants; there are also activities such as writing a paragraph to reflect understanding, making a timeline, and comparing charts.

Chapter four has the heading: "Light Up the Class." The possible "element" is making a simple circuit for a bulb to show *off* and *on* features. The possible "linkages" include comparing pictures to find the circuit that can work, and a timeline; there are also pictures of bulbs, wires, a switch, and batteries.

Chapter five has the heading: "Key Features of Electrical Circuits." The possible "elements" include connecting the pictures of wires, batteries, bulbs, and switches to the circuit diagrams using symbols. The possible "linkages" include pictures, circuit diagrams, and activities on the use of circuits.

Chapter six has the heading: "Different Needs, Different Circuits." The possible "elements" include understanding parallel and series circuits. The possible "linkages" include pictures, differentiating between the pictures of the circuits, the use of examples, and writing to reflect understanding.

Chapter seven has the heading: "Fixing Electrical Problems." The possible "elements" include comparing circuits that work and those that cannot work, broken appliances, and repair factors. The possible "linkages" include comparing pictures to find which circuit will work and which will not work, a chart to show troubleshooting with circuits, and a letter with a picture to find repair problems.

Chapter eight has the heading: "A Special Kind of Electricity—Static Electricity." The possible element includes static electricity. The possible "linkages" include a picture of thunder. The use of "linkages" is given by showing the picture of a computer screen with an advertisement of a magical balloon. The characteristics of the balloon are used to show the presence of static electricity. Other types of "linkage" are the activities to write about static electricity.

Chapter nine has the heading: "Learning About Magnets." The possible "elements" include introducing permanent magnets and electrical magnets. The possible "linkages" include pictures, experimenting with magnets, and making a timeline.

Chapter ten has the heading: "Electrical Picker Uppers." The possible "elements" include making an electromagnet and comparing its strength. The possible "linkages" include pictures, and a timeline on the discovery of generators and electric motors. There is no circuit diagram using symbols that is given for the electromagnet. There are several small boxes and colorful subheadings given.

Chapter eleven has the heading: "Talking around the World—Thanks to Canadians." The possible "elements" include the inventions made in the field of telecommunication with especial emphasis on Canadian inventors. The possible "linkages" include old and new forms of devices for the telephone, and a list of Canadian inventors in the telecommunication field. Among the list of inventors is the name of a fifteen year old that developed the pulsating generator.

Chapter twelve has the heading: “Electricity—Use it Carefully.” The possible “elements” include saving electricity by giving a mathematical comparison of money spent on kWh usage. The possible “linkages” include pictures, charts, and examples.

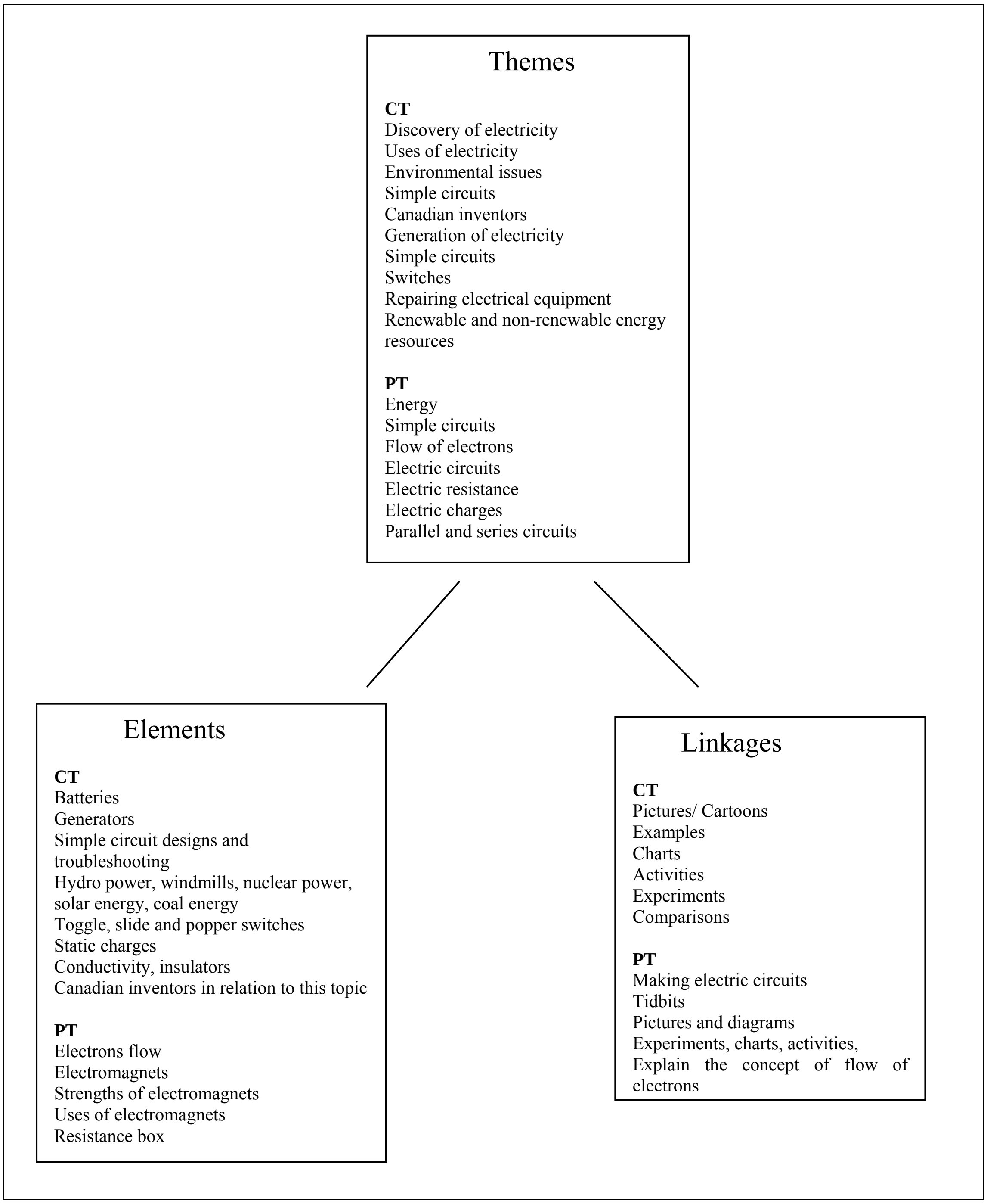
Chapter thirteen has the heading: “Conserving Electricity.” The possible “elements” include saving electricity in Canada. The possible “linkages” include examples of making an action plan using a rubric. The value of the use of multicultural role models in science reinforces students learning (Hartman and Glasgow 2002), and it can also work as a “linkage.” The textbook “Electricity” provides a picture and a short introduction of a scientist in this perspective. The textbook also gives some review questions and a summary in point form.

The related chapters analyzed for the **textbook from Pakistan** include the following elements and linkages. Chapter 15 has elements related to electric circuits, electric resistance, electric charges, parallel and series circuits. The possible linkages include making electric circuits, tidbits, pictures and diagrams. It has also used an analogy of water flow to explain the concept of flow of electrons. Chapter 16 on electromagnet includes elements related to electromagnets, strengths of electromagnets, uses of electromagnets. The possible linkages include making electric magnets, tidbits, pictures and diagrams. Overall the amount of contents included in the textbook from Pakistan is less than the Canadian textbook.

The overall breakdown of “elements” and “linkages” refers to some commonly observed features of the text. Chambliss (2001:263) has discussed “how things happen” as compared to “why” to help children understand the scientists’ view more effectively. The comparison of “elements” and “linkages” along with sentence analysis (Table 5 and 18) show a lack of evidence on explaining scientific reasoning behind the change of the forms of electricity. The enriched link between “elements” and “linkages” is closely associated with explanation and experimentation. This discussion concludes that the textbooks can also enhance the connection between the “elements” and “linkages” by providing some explanation based on scientific reasoning rather than relating to the uses of certain items in everyday life (Figure 25). Perhaps Grade six students can make some observations as a result of the given activities in the textbook. This may, however, be a very challenging task for them to discover the details of the scientific processes behind the activities. Students at this age can develop science concepts through a gradual learning model to grasp the connection between reasoning and observation. Chiu and Lin (2005) have also argued in favour of this standpoint, based on their study on teaching grade four students on the topic of electricity.

The author also uses sentences to reflect metadiscourse. Some scholars believe this process promotes readers’ interest by direct communication, such as “You recall in the first chapter that you learned…” (DiGiuseppe 2007:20).

Figure 25: Deconstructing the textbook design for CT & PT (adapted from Chambliss and Calfee 1998)



5.4. Comparison of various framework results with research questions

Research questions for this study are:

1. To intnd to explore the evidence of explanatory understanding in the two textbooks (from Canada and Pakistan) on the topic of electricity for Grade 6 students (based on the count of keywords, classification of sentences and other comparisons).

2 The second research question is intended to explore the evidence of certain key-words in the students' writing from the experimental and control group.

3. The third research question explores if the students in the experimental group scored higher than the control group in the same multiple choice test when the students in the experimental group were given the opportunity to learn from the same textbook and some additional resources.

The three research questions are first compared with the **study from Canada**. The **first research** question on lack of concern for explanatory understanding can be closely compared with data collected for sentence classification. Nonetheless, the deductions are possible from other responses of students and textbook contents. The data collected from the **textbook of Canada** on sentence analysis shows that sentences that provided no reason is 87.93%, while the sentences that provide a reason are 12.06%. The analysis also finds that no sentences are used to explain the concept of electricity in relation to the "flow of electrons." Although the number of sentences without reason is about 75.87% higher than the cause sentences with reasons, it is not necessary that all "reason-based" sentences are designed to explain the concepts related to the phenomenon of electricity. For example, a sentence in the textbook analyzed is "if you want to operate a radio or walkman, you need batteries" (Campbell et al. 1999:4). Despite containing the linguistic attribute of cause-and-effect, the reasoning for the scientific phenomenon is not intended in this context.

The analysis of textbook design shows some examples of "elements" and "linkages" used in the textbook design that can be tightly linked to form meaningful conceptual connections (theoretical and practical details given in the framework of the document from Chambliss and Calfee 1998). Under the heading "discussion in relation to textbook presentation and comprehension models" (subheading 5.4.2), logical questions are raised, along with specific sentences of the textbook and compared to link with comprehension models.

The textbook emphasis on making circuits also needs explanation of what might be happening in the wires, bulbs, batteries, and, switches. Why were certain things conductors and why were others insulators? What happens when the switch is OFF? There is more to learn in terms of explanatory understanding beyond the common observation of something that appears not to function. The textbook analyzed has a lack of evidence of this type of explanation to elaborate reasoning. This comparison gives some indication (within the dimensions of the frameworks used) of lack of concern for applying opportunity to make explanations for the conceptual basis that underpins scientific reasoning. Although explanation has its limits (cf. Knowels 1990), children can have some understanding of the explanations of scientific concepts (Keil and Wilson 2000). The responses of students in both groups also indicate that students in the experimental group have shown more evidence of the use of explanation in text and pictures (Table 15, 27), as compared to the control group. Perhaps one reason was the exposure of the experimental group of students to other resources.

The **second research question** on the use of keywords can be compared with the lexical-conceptual profile (25 keywords) compiled on the basis of the students' writing in both groups (Canada). The data collected for the lexical-conceptual profile from both groups (Table 15 and 16) shows that students in the experimental group have used more lexemes/keywords as compared to the control group in the Canadian study. Students in the experimental group have shown zero frequency for the keywords: radiation, electromagnetic, physical, attraction, and repulsion. On the other hand, students in the control group have shown zero frequency for the keywords: matter, radiation, electromagnetic, physical, attraction, particles, repulsion, work, machine, and current. The common keywords with zero frequency in both groups are: radiation, electromagnetic, physical, attraction, and repulsion. The keyword *electron(s)* has a relative frequency of 9.39% in the experimental group as compared to 4.40% in the control group. This discussion also confirms that students in the experimental group have used more keywords (25 lexemes/keywords were analyzed in this category) as compared to the control group. There is the possibility to make deductions based on this data and its broader analysis —that the textbook use can be further enriched with the use of other resources. Within the parameter of this research frame, it is observed that grade six students can learn about the concept of electricity in relation to the flow of electrons and some of its related concepts (which is also given in the Ontario curriculum), if it is reinforced with useful resources containing analogies, concept maps, and effective text for this age group.

Learning has a range of factors that cannot be easily regulated, examined, and quantified. The dynamics of all variables that can influence the reading and writing of the grade six students in both groups cannot be numerically indicated in a complete format. The commonality and differences in the lexical-conceptual profile of both groups and the document analysis of the textbook provides some comparison of the factors that might have played a role in learning from this textbook. There was a presence of a higher number of "reason-based" lexemes in the experimental group, as compared to the general-notion related lexemes in the control group. The use of additional learning resources may have played a role in augmenting those conceptual links for the experimental group, in both studies. The control group did not use these supplemental resources, and this may have caused the reduction in the number of lexemes used. In contrast, the control group shows less use of "reason-based" lexemes, where learning was dominated by the textbook and not the additional resources. Some of the deductions from these comparisons can facilitate textbook designing and promote further research for textbook analysis, especially in the Canadian and Pakistan's context.

The **third research question** based on the better performance of the experimental group (Canada) in the multiple choice test can be confirmed with the data analyzed in Tables 10, and 11. Based on the statistical analysis, the data show that students in the experimental group have performed better than the students in the control group (t-Test and other statistical analyses are shown in the Table 13). This analysis provides one aspect of the students' learning that can be seen in view of the other frameworks of analysis. More research is suggested to understand the students' error analysis, the multiple components of the textbook design and the micro-level analysis to examine the students' cognitive styles.

5.4.1. Research questions in relation to the research frameworks for the study from Pakistan

The **first research question** on the lack of concern for explanatory understanding can be closely compared with data collected for sentence classification. And the deductions are possible from other responses of students and textbook content analysis. The data collected from the relevant chapters of the textbook of Pakistan on sentence analysis shows that sentences that provided no reason is 91.03%, while the sentences that provide a reason are 8.96%. The textbook from Pakistan uses analogy of water flowing through pipes to explain the concept of flow of electrons. There is no picture given to make links between the two analogies. Although the number of sentences without reason is about 82.07% higher than the cause sentences with reasons, however it is not necessary that all "reason-based" sentences pertain to explain the concepts related to the phenomenon of electricity.

The **second research question** on the use of keywords can be compared with the lexical-conceptual profile (25 keywords) compiled on the basis of the students' writing in both groups of students from Pakistan. The data collected for the lexical-conceptual profile from both groups shows that students in the experimental group have used more lexemes/keywords as compared to the control group. Students in the experimental group have 115 relative frequency for the keyword *energy* as compared to 9 in the control group. For the keyword *electron(s)* the experimental group has 10.37 relevant frequency which is much higher than the 0.6 relevant frequency of control group (Table 27 and 28). This discussion also confirms that students in the experimental group have used higher number of keywords as compared to the control group. Within the scope of this research frame, it is observed that grade six students can learn about the concept of electricity in relation to the flow of electrons and some of its related science concepts. The use of additional resources for learning has made some improvement in the student responses. The overall concept formation process has multiple aspects and this analysis can be compared within the given parameters of research.

The **third research question** based on the better performance of the experimental group (Pakistan) in the multiple choice test can be seen in the relevant Tables 22 and 23. In the Tables 24 and 25 the details of t-Test, mean and other measures are given. The statistical analysis shows that students have performed higher scores in the experimental group as compared to the control group.

5.4.2. Comparison of lexical-conceptual profiles in relation to textbook analysis, experimental and control group responses

Traditionally, educators, psychologists, and linguists categorize concepts as a general notion of ideas or objects that are members of a category with common properties (Woolfolk et al. 2000; Mintzes Wandersee and Novak 1998). There are many other ways theories have been developed to define concepts, prototypes, graded membership, and exemplars. Graded membership defines the extent to which an item belongs to another one. When comparing concepts attained by reading a textbook it is not easy to find how each student is forming concepts. The best way is to collect data that shows some indicators for comparison. In this context, the explanatory conceptual reasoning for the phenomenon of electricity is closely associated with atoms and electrons, in contrast to the everyday use of electricity in home and school. Therefore, document analysis and student writing responses can give some pattern to explore the presence of use of certain keywords in contrast to the others. The document analysis method applied on the **textbook CT** that out of 10,350 keywords compared, the uses of the words *electrons*, *protons*, and *atoms* are not listed even once (Table 6). The total number of words compared from the relevant chapters of the **textbook PT**, was 2748 and the number of key-word for electron was found 12 or 0.4%. The details of other keywords are given in the relevant Tables. This data gives an important indication of the pattern of the explanatory nature of the textbook. If a textbook shows concern for the explanatory understanding of electricity students have to understand the role of electrons as a basic underlying phenomenon. Although it is difficult to predict how far each grade six student will understand this process, the process of thinking with explanation has to be in place to distinguish between the learning to use electricity and to try to understand how and why it happens. Obviously, the grade six students may not be able to see the electrons, nor can they easily explore this by making circuits, making a list of the use of electricity, or a timeline.

The data collected from the **textbook CT**, on sentence analysis shows that sentences that provided no reason is 87.93%, while the sentences that provide a reason are 12.06%. The data from the relevant chapters of the **textbook PT** shows the percentage of sentences that convey no reason is 87.93%, as compared to 12.06% for sentences that give a reason. This evidence of a lower number of “reason-based” sentences is not a direct or simple relationship for explanatory understanding. However, this numeric indication has to be seen in the perspective of other learning and research factors (student responses, text design analysis of “elements” and “linkages”). This logical deduction is also similar to the analysis of the clause frequency test conducted by Newton et al. (2002).

To answer the question whether grade six students can reflect higher level "conceptual graded membership" to the electron flow to relate to the phenomenon of electricity, some deductions can be made from the work of the students in the control and experimental group. A writing sample of the students from Canada in the experimental group have a 9.39% relative frequency for using the word *electron(s)* as compared to the control group where this frequency is 4.4% (Table 15 and 16). The writing task was comprised of writing and drawing pictures as part of the same cognitive activity, therefore, the lexical-conceptual profile can also be compared with the framework of pictures to draw some possible conclusions. A higher level of contrast emerges in the pattern of pictures made by students in both groups of the Canadian study. Students in the control group have made no picture on atoms or electrons, whereas 65% of students in the experimental group (Canada) have made pictures related to atoms and/or electrons. The writing sample of the students from Pakistan in the experimental group has a 10.37% relative frequency for using the word electron(s) as compared to the control group where this frequency is 0.6% (Table 27, 28). This trend of Pakistan study is also observed in the study from Canada. Perhaps one can also consider further research for this age group of children on the use of text and pictures about the flow of electrons and how this process can facilitate their learning.

The pedagogical limitation of predicting all contributing factors in the concept formation of n=60 in each group is evident. However, the reflection of the students' lexical profile and picture designing pattern indicates a higher number of reflection of electron related graded membership. Students from Canada have made more pictures to explain their ideas with their own text as compared to the students from Pakistan. Overall, the results of those studies show the usefulness of introducing grade six students to learn about the underlying reasoning for the phenomenon of electricity.

5.4.3. Comparison of multiple choice test with students' writing responses

The data collection comprised a variety of frameworks to observe and examine various patterns of textbook understanding and reflections of the learners' work. The use of multiple choice tests also provides data to compare the contrasting patterns with correct and distracting answers. The statistical analysis of multiple choice tests (Table 10 and 11) of **students from Canada** shows that students in the experimental group (n=60) scored higher than the students in the control group (n=60). When students had to answer "true or false" for the statement "electricity has close relation with the concept of atoms and electrons," 57 students in the experimental group picked the correct answer, as compared to the control group where 43 students picked the correct answer. For the multiple choice test question "the flow of electrons has close relation with the concept of electricity," 45 students in the experimental group picked the correct answer as compared to 42 students in the control group.

The number of students relating electricity to atoms and electrons is much higher in the first statement as compared to the other. While logically comparing, the statements vary only for the word "flow of electrons." The role of distracters in the multiple choice test may lead to certain specific selection patterns (Fraenkel and Wallen 1993; Gay 1996). If the number of students who have made pictures to show atoms or electrons to explain the concept of electricity is compared, 39 students in the experimental group have made pictures as compared to none in the control group. The higher number of pictures in this category also indicates some influence of learning from the contrastive exposure to the notion of atoms and electrons in this context. The number of students who have related the concept of electricity to "atoms/electrons" correctly in the multiple choice test of the experimental group is 57 and 45 for the two statements mentioned above, while the number of students who have made pictures is 65. In the control group, the number of students who have related electricity to "atoms/electrons" in the multiple choice test is 43 and 42 for the two specific questions mentioned previously, and the number of pictures associated to it is zero. The number of pictures made by students shows the use of various other diagrams to show their concept of electricity, such as the function of a simple circuit is the second highest number (23.33%) in the experimental group (Table17). The comparison of the control group for the simple circuit is 3.33 %. This shows a clear variation of 23.33% in the experimental group with 3.33% in the control group. The pattern of repetition of simple circuit diagrams (bulb, wire, and battery) is higher enough to conclude that students in the experimental group more closely linked their iconic representation to a simple circuit diagram as compared to the control group.

The statistical analysis of multiple choice tests (Table 22 and 23) of **students from Pakistan** shows that students in the experimental group (n=60) scored higher than the students in the control group (n=60). When students had to answer "true or false" for the statement "electricity has close relation with the concept of atoms and electrons," 50 students in the experimental group picked the correct answer, as compared to the control group where 49 students picked the correct answer. Perhaps students may also have observed the link between electrons and atoms from the textbook PT (pg.155) in which it says: "The flow of electrons in an electric circuit is like water flowing from higher level to lower level through a pipe. In the same way, the electrons flow from the end with more electrons to the end with less electrons through the wire." In response to the multiple choice test question "true or false" for the statement "electricity can not be changed to other forms of energy," 40 students from the experimental group of Pakistan selected the correct answer as compared to the control group in which 23 students selected the correct answer. This conceptual process may also need further research to explore the clarity between the pedagogical and scientific interface of this challenging concept for Grade 6 students. Many textbooks have less emphasized on the links between electricity and energy to distinguish between energy transformation (change of forms of energy, such as light, heat, sound) and energy transportation (energy move from a battery to a bulb through wires). This conceptual and learning resource link needs further research from the perspective of theory, research and practice. This idea is further explained under the sub-heading 5.2.3. The comparison of students' writing responses also indicates that students used higher number of lexemes in the experimental group for the term "electron" (Table 27, 28). The trend emerged from the student responses from Pakistan shows an enriched response came from the students in the experimental group. The interplaying factors and the role of a range of other variables may need further research to explore the ways to improve the learning pathways. An important aspect is to research about the scientific concepts and the textbooks presentation models along with students' changing needs.

This discussion and the comparison shows students at grade six levels reflecting their learning responses closer to the ways of selection and use of teaching resources, although all learning factors cannot be clearly quantified. The need for developing curriculum outlines and textbooks with more explanatory items requires further research to compare the use of various texts, diagrams and other factors of science education linguistics.

5.4.4. Textbook pictures (CT and PT) in comparison to student responses

The use of pictures in the textbook CT shows nine black and white pictures, 62 camera or computer designed pictures and nine charts/tables. The classification of the theme of the textbook pictures shows that page numbers 8, 15, 16, 17, 18, 19, 20, 21, 22, 24, 42 depict bulbs, LEDs, wires, switches and batteries to indicate circuit(s). This is the larger group of pictures. Renewable energy resources are shown by nine pictures, from page 11 to 14. Three pictures given on pages 5, 32, and 38 relate to the historical discoveries of the telephone, battery design by Volta, and the lubricator for the steam engine (some examples of those pictures are shown in Figure 26). There are a sparse number of pictures that use cartoon style representation. For example, the use of electricity in daily life (p. 2-3), the movement of a frog's leg to show the presence of electricity (p.4), the use of garbage to make electricity (p.5), the use of electricity in the home and a globe to link to environment issues (p.36). During the classroom interactions, some grade six students were confused when they read this line from CT: "An example of this is Elijah McCoy, the inventor of the automatic oil cup and the lawn sprinkler" (Campbell et al. 1999:38). Students looked at the pictures and when they related to the text, many of them started guessing if this picture is about the automatic oil cup or the lawn sprinkler (Figure 26).

Figures 26 and 27. Textbooks pictures.

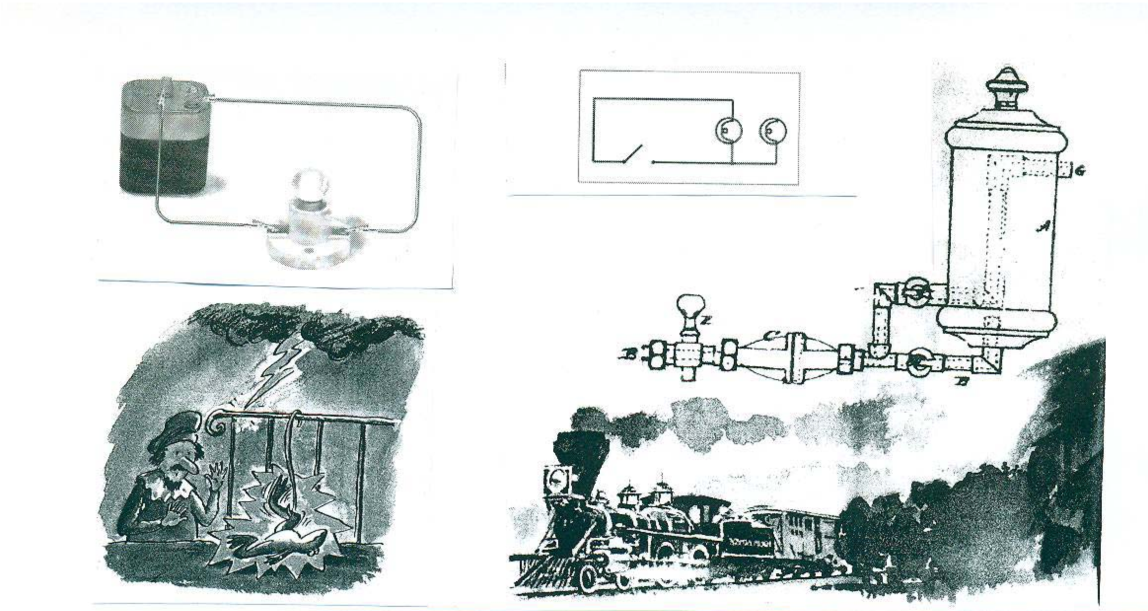


Figure 26: Some examples of pictures in the textbook (CT) "Electricity-Science & Technology", historical invention, circuits, camera picture and cartoon. Courtesy of Addison Wesley Canada.

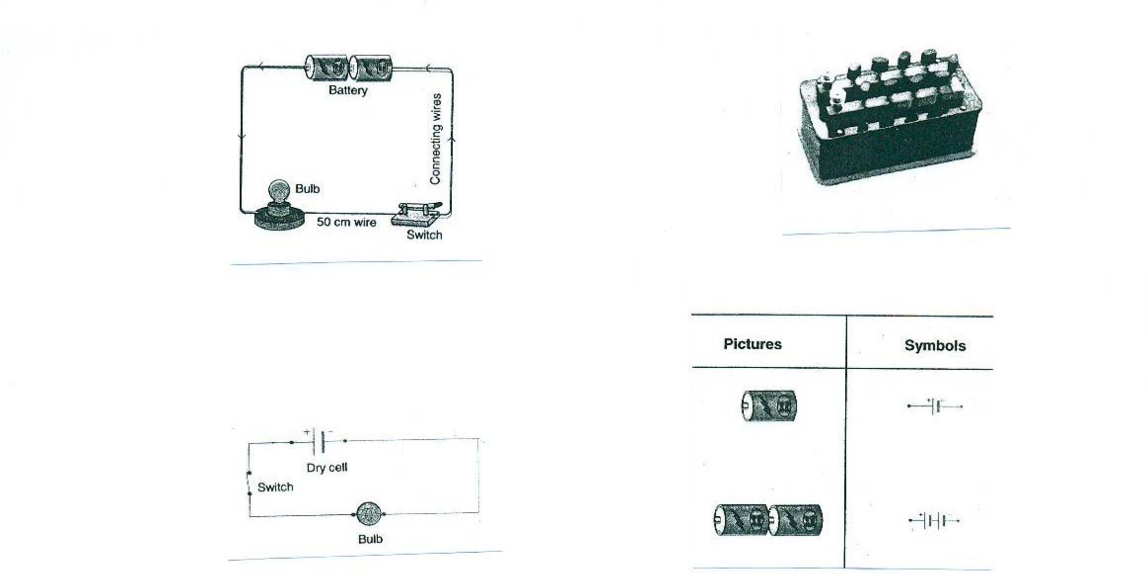


Figure 27: Some examples of pictures in the textbook (PT) "Science 6", circuit, picture, circuit diagram, symbols and equivalent pictures. Courtesy of Punjab Textbook Board, Lahore, Pakistan.

The textbook PT has not included any cartoons to explain the concept of electricity. There is no black and white picture in the textbook PT on the related chapters analyzed. There are nine diagrams indicating circuits. The pictures and circuit diagrams show the use of circuits (p.155 to 161 and p.167 to 168). The links between symbols for electrical circuits and a related picture is also shown for example, one dry cell and batteries (some examples of those pictures are shown in Figure 27). As theory and research indicates, the use of more specific captions can enhance the learning value of the textbook pictures (Alesandrini 1984; Roth et al. 2005). Roth et al. (2005) have conducted a comprehensive analysis of the text and pictures in school science books. One of the implications of their analysis is applicable in this context. According to Roth et al. (2005:257):

> Every inscription should have an appropriate caption associated to it via an indexical reference in the main text. An appropriate caption may contain more than just an identification of the object or the phenomenon presented in the inscription and referred to in the main text. The caption should add enough text such as to guide the reader through a perceptual analysis that lies at the basis of any interpretation of the inscription, identifying relevant details and associating the figure with the main text.

The use of pictures in the textbook has limited evidence of providing scientific reasoning. Many of the above mentioned pictures in the textbook are designed to show the use of electricity or how to make simple circuits. If the data obtained from the picture analysis (Table 3, 4) is compared with the data obtained by the student use of keywords (Table 15, 16, 27, 28), the comparison shows the students have used less keywords. Correspondingly, there were also less lexemes/keywords used in the textbook. This does not mean there is direct relationship between the textbook use of keywords and the student responses, as there could be other outside factors that can contribute to the students writing responses in a certain way. Newton et al. (2002) have also indicted reasoning for the clause frequency test, and despite not claiming direct or simple relationship, they have made a deduction on the presence of certain possibilities to improve explanatory understanding in the textbooks.

This analysis of this study includes various frameworks as mentioned previously. The collective evidence of the frameworks' data and deductions on curriculum and text design can provide patterns to improve explanatory understanding using text designs with more integrated "elements" and "linkages." The analysis shows the contrast of experimental group results and the control group for the study in Canada and Pakistan, in terms of using a higher number of keywords, particularly for "atoms," and "electrons."

5.5. Consolidating discussion

Comparing the data against the three research questions, it is concluded that the science textbooks CT and PT shows a lack of concern for the explanatory understanding, based on sentence analysis, keyword lexical-conceptual profile, and other aspects of discussion. In both textbooks analyzed (CT and PT), the percentage of sentences "with a reason" is very small as compared to the sentences "without reason". There is no sentence found in the Canadian textbook that explains atom-related explanatory reasoning of the electricity concept. The textbook PT also lacks in explaining the flow of electron concept along an illustration. The paragraph analysis shows that there were only a very small number of the paragraphs which explain something using a reason. In contrast, the paragraphs discuss the daily-life use of electricity are much higher. This finding also indicates the textbook analyzed shows a lack of concern for explanatory understanding.

In both studies from Canada and Pakistan, a relatively larger number of students in the experimental group show “electrons” and “atoms” to explain the process of electricity (details of data shown in chapter 4). A relatively larger number of students in the control group show lack of use of specified lexemes/keywords in their writing. The pattern of picture count also shows a higher number of pictures made by the students in the experimental group, as compared to the lack of pictures drawn by the control group to explain their understanding of electricity; this aspect is more evident in the Canadian study. In both studies from Canada and Pakistan, students in the experimental group also achieved relatively higher than the control group in the multiple choice test. The statistical comparison supports this conclusion (Chapter 4 provides data of various frameworks). The statistical data shows that there is some reflection of the contrast in the student learning process and the student responses in both groups. While the learning process is comprised of multiple components, and despite all of the challenges of various cognitive styles in the student population, there is some possibility to design textbooks to reflect explanatory sentences and pictures. Textbooks still play an important role in learning therefore, improving textbook designing is crucial to make learning effective for all students.

Despite economic and administrative challenges, more effective textbook designs have to be stressed and supplemented with other resources. In many cases, textbook writing is influenced by the demands or *curriculum expectations*, therefore explanatory understanding can also be incorporated in the curriculum outlines. The interconnected nature of the two documents can be applied as a source of conceptual development.

The paragraph analysis shows the category 1 has the highest occurrence among the three categories (Table 8 and 20). The paragraphs related to "think about" and "question asking" is in lower percentages. The paragraphs related to providing some type of reasons in the category appeared in the lower frequency in both textbook (CT and PT) analyzed. This pattern also shows a smaller proportion of paragraphs about the use of explaining reasons. The trends of paragraphs in the Canadian and Pakistani textbook have a very close frequency for the category 1.

Canadian and Pakistani textbooks also need local level textbook analysis studies using various methods. Explanatory understanding needs to be promoted in science textbooks using various strategies. Textbook designing is more effective when the text is more balanced as described by Chambliss and Calfee (1998). An important factor for effective text design is “text design reflects expert models or principles” (ibid.: 116). The link of atom related explanation of the concept of electricity becomes more meaningful in this context. Further research is needed to explore the in-depth processes of learning through various designs of textbooks. Additionally, textbook analysis methods can be further developed for more consistency in this field.

Although picture analysis is not the focus of this study, this study has included many student-made pictures that can also promote further analysis and research studies of children’s learning from various dimensions.

Explanatory understanding is not an isolated entity in the learning environment. It is embedded in the combination of a range of teaching and learning strategies (Figure 6 and 7). For future research and learning resource preparation, there is a need to increase the use of explanatory sentences, explanatory pictures, explanatory words, explanatory analogies, explanatory glossary, and explanatory refutation text. In doing this, textbooks can more effectively facilitate explanatory understanding. Roth, Tobin and Ritchie (2001:87) assert:

> In face-to-face interactions, talk cannot be reduced to uttered text alone. Rather, meaning emerges from the interaction of multiple modes of communication that includes the coordination of hands, eyes, ears, and signs (words and drawings). Therefore, we have to account for the fundamental interdependence of hands, eyes, ears, and signs in order to understand “conceptual” talk and thinking in science classrooms organized as linguistic communities.

The study is intended as a contribution to the improvement of the textbook contents, explanatory sentence structures, use of pictures, and curriculum outline on applying explanatory understanding and aligning that in the textbooks. The study is also intended as a contribution to the search for ways to improve learning in the elementary level classrooms in Toronto and Pakistan. This research was based on a textbook analysis on the use of certain lexemes, sentence analysis, paragraph analysis, and textbook design analysis. The other feature of this study was that students worked in two groups of sixty students in each group. The experimental group used the textbook selected for the analysis and some additional resources, and the control group used the textbook to explore the variations that appear in both teaching models. Student responses were collected by multiple choice tests and writing based on their understanding. This process helped to find qualitative and quantitative features. This study also explores the local curriculum expectations that influence textbook designing and classroom delivery of the curriculum. The data collected by multiple modes is useful for making further extended comparisons. Although previous studies on textbooks are not found at grade six science levels in Ontario, some relevant studies indicate that textbooks show lack of concern for explanatory understanding. Textbook analyzed from Pakistan was not analyzed in the past for explanatory sentences and student responses. This study aimed at finding the specific contents missing in the textbooks and how additional resources can work in a limited way to fill that gap compared through student responses. Many textbook studies in the past have only focused either on some aspects of the textbook itself or student learning from them, while this study has collected data from both aspects. This chapter presents a summary of the findings of the study conducted on the relevant textbooks, as well as student responses using the textbooks and other resources. The significance of the study and its theoretical implications are also summarized in this chapter. A number of recommendations are made based on this study, which can be applied to incorporate more clear curriculum expectations and effective textbook designing to enhance explanatory understanding. As the new research trends in science education are rapidly moving to use nature of science (NOS) models, this research can also be useful to some extent for making explanatory understanding of NOS contents in the elementary level science textbooks and classroom application.

5.6. Findings of the study

The following findings were made from the results of the analysis of lexeme analysis, textbook design analysis, and student responses:

1. The curriculum outlines from the relevant education policy makers play an important role in shaping textbook contents and design.

2. The Ontario science curriculum needs more emphasis on explanatory understanding of science concepts, particularly electricity and its related strands. This is also a need in the curriculum of Pakistan.

3. Although grade six students have reflected their learning about electricity using atom-related concepts, such explanatory contents are not addressed either in the textbook analyzed or from what appears through the control group feedback.

4. Currently used textbook contents in the given classrooms provide little or no emphasis on the explanatory understanding of electricity.

5. This study also highlights some examples of ambiguity found in the textbook contents which can cause misconceptions for grade six level students.

6. In addition to using science textbooks at the elementary level, the use of appropriate additional books with the contents of electricity in the delivered curriculum is useful to support student learning.

7. Students studied from the textbooks (with less emphasis on explanatory understanding) need more explanation of the reasons behind certain scientific phenomenon. The overall learning environment may also be focused to develop the science concepts. Students can also be encouraged to write their response in the

language this textbook is written. As appears from the responses of the students used the textbook PT; reading a science textbook designed in English language and writing answers in Urdu language, indicates a need to review the goals of education. The role of science education linguistics is also a need in this context. This gap highlights a need and it is time to consider some pathways for the interplay of theory, research and practice in the Pakistani learning environment.

In many instances, textbook designers attempt to align the content and design of the textbook in accordance of the local level curriculum from the policy makers. That design is primarily a reflection of making the textbook acceptable for the places where it will be used. The interpretations of the curriculum expectations of Ontario vary in textbook contents and classroom delivery. In order to bring a change in the textbook, the process is closely associated with the curriculum design given by the education policy makers. Since educators in many schools may have severe time constraints to cover a range of topics, many details of concept formation process are not fully addressed. The use of additional learning resources is one way to enhance the textbook content delivery. Textbook publishing is a lucrative industry and many publishers would like to survive in their business by complying with what policy makers are interested in. Whether change in the policy and publishing model comes or not, this study promotes ideas to fill this gap by showing the examples of explanatory understanding strategies and contents that can be useful to integrate conceptual growth in various curriculum strands. This process also reflects upon the selection of curriculum resources with explanatory understanding contents. The curriculum for the elementary level science textbooks from Pakistan also needs those parameters incorporated. This process will help to design elementary level science textbooks effectively.

The other fact revealed by this study is that grade six students can learn about the atom-related curricular model (cf. Justi and Gilbert 2000; Harrison and Treagust 1996) to connect their understanding with the concept of electron flow, as compared to only being taught about the everyday use of electrical appliances, or observing the use of electricity in various instruments. This study emphasizes on providing scientific reasoning, according to the grade six level, as opposed to only presenting scientific facts, or using an apparatus that works with electricity. If this finding is applied in an extended way in the classrooms, grade six level students can possibly learn on the following themes: exploring reasons beyond our daily observation of the use of electricity, science as a body and knowledge, science as way of thinking and the links between science, technology and society. This study has gathered various examples and discussed the lack of explanatory understanding instances in the textbooks. The role of curriculum design is also critically discussed. Some instances of the science textbooks CT and PT are also discussed to highlight the need for including explanatory “elements and linkage”. From the various framework of this study it is concluded that the inclusion of the curricular model in Grade six level textbooks or curriculum materials has been useful to explain the concept of electricity from the perspective of science educators. The use of additional resources has also shown within the limits of this study that the enriched textual contents with graphics and scientific explanation may facilitate students' learning in a close referential situation model (cf. Tapiero and Otero, 2002; Qadeer, 2013).

This study presents some examples of the use of linkages and elements in the textbook design based on the Chambliss and Calfee (1998) models. The deconstructing science textbook model can promote the use of the right linkages and right elements with the themes for stronger design nets. Textbook design is also linked to explanatory models along with the right linkages, right elements, and themes. If the future textbooks apply those design models as discussed, perhaps students will understand the scientific reasoning beyond our current models.

This study discussed a range of examples from the Canadian textbook (CT) and the textbook from Pakistan (PT) where the textual theme has some ambiguity for Grade six level students. The possible reasons for misconceptions can be addressed by the educators in the classroom and the authors of textbooks. As it is expressed in the textbook designing interaction process among the educators and publishers; the curriculum resources are generally written by teachers, with the support of professional editors, therefore some of those examples provided by this study can also be useful to improve textbook writing and classroom applications. This study collects examples and discusses the importance of communication between all who interact and benefit from textbooks, such as authors, teachers, parents, researchers, policy makers, students, communities, and publishers. The interaction of theory, research, and practice is important in effective textbook designing.

This study calculated the occurrence of the frequency of 25 lexemes in the textbooks analyzed (CT and PT). The study revealed that some lexemes were not mentioned even once, such as electrons, protons, atoms, radiation, electromagnetic, physical, attraction, particles, charge(s), and repulsion. The explanation of the concept of electricity in terms of how a scientist describes the flow of electrons needs the use of some of those terms that are not found even once in the textbook. This finding shows that the textbooks analyzed missed an opportunity for using explanatory sentences linked in explaining the scientific reasoning behind the concept of electricity. In the past, Newton et al. (2002) have conducted a large scale study in the United Kingdom and calculated the frequency of occurrence of certain clauses on a number of textbooks. They concluded that those textbooks also show lack of concern for explanatory understanding.

This study used the experimental approach in two groups from Canada and Pakistan to find the student feedback from CT and PT and some other learning resources. The results indicated that students in the experimental group who used either CT or PT and some additional resources performed higher in the multiple choice test as compared to the control group that used only the textbook. Similar to the textbook analysis of lexemes, the study also calculated the occurrence of 25 lexemes in the students' writing. This study found that students in the experimental group used a higher number of lexemes such as electrons and atoms; whereas students in the control group used such lexemes in very low numbers. The study also found that students use more pictures to reflect their understanding when they are taught with the emphasis of using pictures. Student writings showed that students in the experimental group used more pictures to describe the electron flow, whereas students in the control group used far less pictures. Those findings indicate a possible useful effect of using selected additional resources along with the traditional textbook. The pictures drawn by students were also compared with the curricular models for atoms that are used in the classrooms and how those atomic models have changed as curricular models in the light of scientific discoveries.

Based on the comparison of previous studies in this field, this study highlights the growing need for conducting textbook analysis and curriculum guideline critical studies in Canada and Pakistan, as a large number of textbook studies that are reviewed were conducted in other countries. Overall, the education policy makers need a more vigorous research approach to develop textbook designing from a local perspective. Some major Canadian cities are highly multicultural (Nickles and Walker 2000), therefore textbook designing needs could be different from some other jurisdictions. On the other hand, there are some advantages for incorporating textbook designs for the diverse needs of society. In view of the needs of Pakistan this process can be extended according the local educational needs.

It has become evident from this research study that the need for using explanatory sentences, along with effective concept forming pictures, and captions along with the curriculum guidelines is not fully addressing grade six level conceptual needs. The study collects data to show that the number of reason-based sentences and paragraphs are far less in numbers compared to the sentences that lack reason. When this fact is reviewed in relation to the students' feedback from the experimental and control groups, the study further highlights possible examples where concept explanation was less emphasized in the textbook and the provincial curriculum expectations.

5.7. Significance of this study and research implications

It is hoped that the findings of this study contribute in an effective, albeit minor way for the textbook developers, educators, and policy makers. This study is significant in that it can be applied to enhance explanatory content in textbook designing and curriculum development —to some extent— in many countries according to the specific local needs. The results of the study are relevant for many textbook designing models, as the effective explanation of science concepts is a basic challenge for the educators and authors in this field. Given the challenges of education policy making and textbook designing limitations, this study explores that educators can support their elementary level students' understanding of science concepts with the help of additional resources. If the elementary level science educators are aware of including the explanation to provide scientific reasoning according to the classroom needs, the use of the textbook as a central tool in learning can be augmented in many ways. One of the distinctions of this study from previous studies is that it has applied content analysis on the textbooks and collected student responses through the experimental research method. This process makes data more comparable for content and learner feedback, in contrast with most of the previous studies in which only one type of information was given. Within those two groups for the empirical studies from Canada and Pakistan there were various frameworks applied for data collection, such as sentence analysis, paragraph analysis, and lexemes frequency in the textbook. For the experimental group there were two groups of students; the experimental and control groups, with 60 students in each group. Students in the experimental group used the textbook and some other resources to see the contrast with the control group who used only the textbook. The study signifies the learning of students in both groups based on a multiple choice test, student writing responses, lexeme frequency in the students' writing, and student-made pictures. This study also has a distinction of including Canadian and Pakistani Grade 6 level science textbook on the topic of electricity. Both studies also include student responses within the framework of this research. It is notable that the textbook topic on electricity was selected from the local books in Pakistan and Canada, and the additional resources were the same in both studies for the experimental groups. Despite the culturally and socially diverse student and teacher groups, the results show improvement in the student responses.

The study is also significant in that it can inspire to develop curriculum outlines and textbook designs that can promote NOS themes. The study can be incorporated in textbooks and curriculum outlines through the use of concept formation methods, explanatory understanding, other strategies of learning about science as a body of knowledge, metacognition, the history of science development, and links between science and society. The recent trends in science education are putting significant emphasis on using the themes of the nature of science (NOS) in textbooks (cf. McComas 2008; DiGiuseppe 2007). The development of textbooks from this perspective is in the early stage (Lee 2007) and more resources will be published in the years to come. The research analysis on textbooks is commonly conducted either on NOS or conceptual problems as observed in the recent research trends (cf. Phillips 2006; Lee 2007; Newton et al. 2002; Peacock and Weedon 2002). One of the theoretical arguments this study brings is to develop NOS models with an emphasis on explanatory understanding strategies. The other argument is to facilitate teacher training to incorporate NOS and explanatory understanding strategies. With the changing trends in science education, there is a growing need to train new teachers about the history of science education (HSE) as well. As this study shows that many teachers were selected by the publisher to become textbook writers, training teachers from this perspective can have some impact on the way information is presented to the learners.

Additionally, local level learning environments might reflect on mixed-method research models rather than a single type of analysis model. The need of science textbooks that can help the local communities for a multilingual and multicultural society with an emphasis on explanatory understanding content. It is interesting to note the language factors in both geographical places where the studies were conducted have more than one student and teacher language component along with the understanding science terminology. The use of illustrations is also emphasized in this study.

This study also promotes explanatory models for the developing world science textbooks where science is primarily taught by this main source of learning: textbook. According to Venesky (1992:442)" "in Third World countries, textbooks are significantly more important and are often the only books that students encounter in their studies. In addition, they often show national policy and national will." If the explanatory understanding factor is included in the textbooks, as discussed by the findings and examples presented in this study, textbook designing can be improved in the developing world to some extent. The impact of any changes in the elementary level science textbooks can also be seen from the fact that many well-known publishers of textbooks in the developed world also publish books for the developing world. On the other hand many local level books in the developing world are influenced to some extent by the textbooks from the developed world (cf. Altbach 1988). The use of explanatory understanding factors in the textbook can also promote less use of rote learning and encourage constructivism learning models (cf. Lord 1998). The other factor for developing world elementary level science is to bring explanatory factors more effectively in the curriculum outlines (as discussed by the findings of this study) that have the potential to set goals for the elementary science textbook writing.

Rosenblatt (2011) argues about the right answers and right reasoning. The need for robust foundation and critical thinking "it should be a foundation anchored in understanding and critical habits of mind, not in particular matters of facts and technical terms" (163:ibid). Rosenblatt (2011) uses the examples of children learning language skills, from start to read higher level novels, they learn by simple stories first and then reach the higher level. He emphasized that it is not so that we start teaching them just the vocabulary they will eventually need. Rosenblatt (2011:163) remarks "that is what we should be doing in the sciences. Each level should tell its own story, taking on the deepest issues, pushing the material, and nurturing students' critical reasoning. It's a matter of students building an understanding of their world, not preparing them so that they may be given one." This argument is useful for developing curriculum materials and textbooks with this background in mind.

5.8. Recommendations from the study

The objective of this study is to possibly find ways to facilitate science understanding for grade six level students in Toronto and improve textbooks for this purpose. The study also includes data on the textbook and student responses from Pakistan. It is especially intended as a contribution to consider possible improvements in the textbook on the topic of electricity, commonly used in Toronto and Pakistan. It is extremely challenging to prove that finding any lacking in a textbook can immediately improve on presently used curriculum resources. In general, the learning process is comprised of many components, and the varying compositions of those elements can affect some outcomes. Based on the intentions of this study, some positive steps in these directions can be anticipated from the relevant authorities. In order to meet this goal, recommendations have to be made with the hope for applying them in future academic work.

The **first** item is about exploring elementary level science textbook contents for the linguistic, didactic and science concept indicators pertaining to explanatory understanding, as this need is identified by this study. The science textbook authors have to consider the textual and inscription items that promote explanation according to the elementary level students. The use of language to explain science concepts have to be age appropriate along with introducing the new vocabulary of science.

Secondly, as highlighted with specific examples by this study, some statements in the textbook that encompass a wider range of scientific conceptual applications have to be explained step by step to reduce the chances for misconceptions for elementary level students. The authors of elementary level science textbooks have to be cognizant of the fact that the contents are only referring to the daily life observation of a science-related process or invention and how those items are included for the scientific explanation of those items. This process can be one potential factor in improving the overall understanding of science of elementary level students.

The **third** recommendation is that textbook authors can review the use of various types of analogies to explain the abstract nature of certain concepts of science. The curricular model of an atom (Justi and Gilbert 2000) can be used in the textbooks to explain the concept of electricity to grade six level students (cf. Harrison and Treagust 1996). The use of analogies can further enrich this process of understanding the concept of electricity and other related topics (cf. Chiu and Lin 2005).

The **fourth** recommendation is that while keeping a balance in the curriculum structure, the history of the discovery of scientific inventions can be useful to teach grade six level students. This will help to incorporate the themes of nature of science and partially address the metacognition component in the science curriculum outlines.

The **fifth** recommendation is that textbooks can apply the Chambliss and Calfee (1998) model to improve the textbook design for making an effective net of themes, links and elements that can facilitate student understanding. As Chambliss and Calfee (1998 and 1989) have presented the comparison of textbooks from various jurisdictions, perhaps research studies on Canadian textbooks can also collect data for this purpose.

The **sixth** recommendation is, as informed by this study, that educators can support elementary level science lessons by using additional resources on those topics. One textbook may not include all essential elements and linkages in the text design, therefore additional resources can be selected that will fill the gaps left by the main textbook.

The **seventh** recommendation is that curriculum guidelines, textbooks, and teacher resource guides for textbooks need to emphasize using examples to apply the explanation of scientific reasoning and processes. Teaching elementary level science with this focus can be useful to connect the students' daily life experiences with the science knowledge in a meaningful way.

The **eighth** recommendation is that more research studies are conducted on Canadian and Pakistani textbooks and curriculum guidelines to apply local level data. This process will also work in collaborating science education among the various jurisdictions of Canada and Pakistan. This data will also promote addressing local level needs for elementary level science education. Research studies on Canadian textbooks enhance the application of the mixed-method research (i.e., qualitative and quantitative), which is also recommended in a recent study by DiGiuseppe (2007) that was conducted on the senior high school level chemistry textbook. This model can also be applied for the textbook analysis in Pakistan.

5.9. Suggestions for further research

A comprehensive study on textbook development, student learning from the textbook, cognitive structures of concept formation, the nature of science representations, and curriculum designing requires tremendous resources that are not possible to obtain from this small-scale study. This study is primarily a partial contribution with some limitations for its scope and relevance. In order to continue research from the essence of this study or adding any parallel findings, further research is suggested that can lead to other related aspects of the elementary level science textbook.

One downside of this study is that it focuses on "electricity," which is only one topic of elementary level science. This means that **other topics of science** need further research on a large scale to find the elements and linkages in the textbook design that indicate explanatory understanding. From the science concept perspective, electricity has strong links with many other topics and fields, such as energy, environmental sciences, computers, mechanics, magnetism, matter, sound, optics and many more. This study did not include a comprehensive analysis of other fields of elementary level science; therefore future studies can focus on other strands of science and how they conceptually interface each other. Due to the specific focus, this study did not apply cognitive science tests on students to compare their learning from a textbook. Future studies can apply cognitive science techniques to explore mental models that emerge as a result of learning from certain science textbooks.

Current reforms in elementary level science education have potential emphasis on the informed views of the nature of science. Future studies on textbooks can analyze on explanatory understanding of the nature of science representations from a conceptual and thematic view. Science education has gone through many changes in the past fifty years. The current study only highlighted some important examples of the conceptual barriers explored in the textbook and described by the frontline teachers. Many teachers do not have formal training in science education and its history of development. In future research studies, data can be collected to compare how teacher training with learning about the history of science education can affect the professional growth of teachers, classroom interactions and textbook use and its designs.

As compared and argued in the findings of this study, the textbook development process heavily depends on the curriculum outlines provided by the **education policy makers** (cf. Giordano 2003). Future research studies can apply qualitative and quantitative research methods to explore the effect of education policies, curriculum expectations in Ontario, and how their interactions take place in the learning environment, particularly with regards to textbook designing. Also this type of research can be applied in other geographical locations that can provide more data for extended comparisons.

This study has shown some encouraging effects of **using additional resources** along with the use of the regular textbook. Another additional resource for elementary level science is the internet, which was not analyzed by this study. The use of technology is now becoming more prevalent in many educational environments of elementary level schools (cf. Rushowy 2009). Some of the websites are used to supplement student textbook learning in elementary level science. Research studies on the learning effectiveness of websites designed for elementary level science is still in its early stages. The current study also compared only 25 lexemes from the textbook and the student writing samples. That data was collected for a small-scale comparison of lexemes in a specific environment. This standpoint also gives a rationale to conduct large-scale comparison for other learning environments. The future studies can also focus on how internet and textbook learning is shaping the technologically-based learning for elementary level science. From the point of view of educational linguistics and computational linguistics, a corpus of elementary level science textbooks and science websites for children can be developed to provide research data for analysis and application models for the international research community.

The current study collected data from textbook content analysis and student response to enhance the comparison of various textual and learning factors, yet it is not comprehensive for all educational environments, curricular models, and textbooks. The field of **textbook designing** is a multidisciplinary field for which critical comparisons have to be made from multiple perspectives. For this reason, a single study on textbooks is a partial contribution in the research-based development of educational resources in Ontario and Pakistan. Perhaps future studies, similar or extended critical comparisons will enrich the research continuum for elementary level students.

Science textbooks have much to offer beyond to between the lines, between the words, between the pages and between the pictures. Their encompassing scope from **information presentation modes** to providing explanatory understanding and to develop critical habits of mind to construct arguments is a multi-domain realm. The way the textbooks are used in an educational environment can also relate to the understanding of textbooks by the user. With multiple factors developed and encoded in the textbooks, it emerges as a question to understand further about the nature of textbooks to collaborate with the nature of science and the nature of communication.

Appendices

Appendix 1

Multiple Choice Test

Name: Grade: 6____

Please **choose the answer** that is best suited according to your understanding

(1) Electricity is a form of

a) Energy

b) Money

c) Wood

d) Elasticity

(2) Electricity is flow of

a) Electrons

b) Batteries

c) Circuits

d) Election

(3) Static electricity is caused by

a) Sleeping

b) Friction

c) Eating

d) Watching

(4) Current electricity is made up of

a) Cars without gas

b) Millions of moving electrons

c) Insulation material carrying negative charges

d) Clouds in the sky

True or false

(1) Electricity has close relation with the concept of atoms and electrons

True False

(2) Flow of electrons has close relation with the concept of electricity

True False

(3) Electrons have negative charges

True False

(4) Electrons are not very closely attached to the nucleus of the atom

True False

(5) Electricity is a form of energy

True False

(6) Power means the rate at which energy is used

True False

(7) Power means distance between the two things

True False

(8) Electricity has no relation with the concept of atoms and electrons

True False

(9) Protons in the outside orbit of the atom flow to produce electricity

True False

(10) Static electricity is more useful for our home appliances than current electricity

True False

(11) Electricity is the only form of energy that is useful in our homes

True False

(12) Static electricity is produced only by the batteries

True False

(13) Electricity can not be changed to other forms of energy

True False

(14) Telephone produces electricity for our home

True False

(15) Nuclear energy can not be used to produce electricity

True False

Appendix 2

Writing task for the students

Science Electricity

What is electricity?

Name Grade 6____

Students will write about one page to reflect their understanding of the concept of electricity. The teacher will discuss the outline of writing prior to the assignment. The concept of electricity will be explained in the best possible way to reflect understanding. Students are encouraged to think these questions before they write. Who I am writing for? Why am I writing this? What do I know about electricity? How can I group my ideas? How will I organize my ideas?

[Note: This questioning technique before writing is adapted from the work of Pressley (2003), In: Hand book of Psychology 2003, page 345]

Appendix 3A

Sentence analysis of the textbook

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
1	Electricity.	WR
2	It's all around you.	WR
3	It’s invisible.	WR
4	It can be used for many purposes such as listening to music, finding your way down a dark path, or talking to a relative in another part of Canada.	WR
5	You will participate in an electric adventure as you learn about electricity.	WR
6	Electricity is everywhere!	WR
7	It can be found in your house, your school, at the soccer field, or baseball diamond.	WR
8	Use the illustration on these two pages.	WR
9	Identify and list as many examples as you can of electricity being used.	WR
10	If you want to operate a portable radio or walkman, you need batteries.	WR
11	These batteries can be purchased at most stores.	WR
12	Sometimes they are rechargeable.	WR
13	This has not always been the case.	WR
14	Imagine yourself back in the past, before television, cars, and light bulbs.	WR
15	You are now 200 years back in time.	WR
16	Canada will not become a country for another 50 years.	WR
17	There were no fridges to keep the food cold like the fridges we use today.	R

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
18	This is because there was no electricity.	R
19	What do you think people used to keep their food cold?	WR
20	Draw what you think was used to keep food cold.	WR
21	Review the drawing of your fridge with others in your class.	WR
22	Aren't you glad that we have access to electrical devices like fridges, ovens, and computers?	WR
23	How did humans discover and harness electricity?	WR
24	Believe it or not, it all started with a frog's leg, a brass hook, an iron railing, and a lightning storm.	WR
25	Luigi Galvani was an Italian scientist and a medical doctor.	WR
26	In 1786, while examining a dead frog, he noticed that a spark could make the frog's leg move, when two different metals were touching the frog's leg.	R
27	He was curious as to why this happened.	WR
28	He wondered if he could repeat the observation under different conditions.	WR
29	Galvani guessed that the spark travelled from one metal, through the frog 's muscle, and then into the other metal.	WR
30	While this later turned out to be the correct guess, he didn't know how this could happen.	WR
31	But he was determined to find out.	WR
32	As the next lightning storm approached, Galvani used a brass hook to hold the frog's muscle and attached this hook to an iron railing.	WR
33	He knew the storm would create a spark.	WR
34	The spark could then travel between the brass hook and iron railing to make the muscle move	R
35	As the rain came down and the lightning flashed around him, he observed and recorded the changes to the muscle.	R

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
36	He noticed that the muscle moved! Using his observations, he proposed that the muscle moved because of electricity.	R
37	While there was much excitement in his town and country about the discovery of electricity, it was only the beginning of the investigation for scientists all around the world.	WR
38	If a person has a leg or arm amputated, it is usually replaced with a device called a prosthesis, or artificial leg or arm.	WR
39	Today, scientists are investigating ways to make artificial legs or arms move.	WR
40	Just like Galvani's experiments, they are using electricity to make an arm move up and down or a leg bend at the knee.	R
41	In 1796, after Galvani's muscle experiment, another scientist from Italy, Alessandro Volta, wondered if he could make electricity rather than observe it.	WR
42	Instead of using a frog's muscle, Volta used different liquids.	WR
43	He placed these liquids in bowls and then connected the bowls with pieces of metal.	WR
44	Volta discovered that when he used saltwater in the bowl and connected the bowls with copper and zinc metal, he could produce a spark.	R
45	This was very exciting because he designed a chemical cell which would soon become a battery!	WR
46	In 1967, then 17-year-old Richard Keefer of Ontario invented a battery that could run on garbage!	WR
47	The battery lasted longer than store bought batteries and cost about the same price.	WR
48	You now know about the discovery of electricity and batteries by scientists over 200 years ago.	WR

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49	It is time for you to explore the characteristics of electricity.	WR
50	Before you start, write down your thoughts about the following statements and make sure to include an explanation if you can.	WR
51	Can you make electricity with a fruit and six cents?	WR
52	Can electricity make objects move?	WR
53	Can electricity go through a toothpick, fork, or straw?	WR
54	Before you make a decision, it is important to have all the information that will help you make that decision.	WR
55	Would you buy a game for your friend without knowing if she would like it?	WR
56	Would you go on a trip without making sure you knew how to get there and where you would stay?	WR
57	You can find some of this information by asking someone.	WR
58	Other information needs to be researched.	WR
59	When you do your research, it is important to keep all the information organized.	WR
60	One method of organizing information is in a + and - chart.	WR
61	This type of chart allows you to identify the positive and negative characteristics of the particular subject you are studying.	WR
62	Look at the chart.	WR
63	This is an example of how one student listed the information using the + and - to help him decide if he should buy a bicycle.	WR
64	A + and - chart can also be used for collecting science information.	WR

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65	You are going to read about five different ways to generate electricity.	WR
66	Each way has positive and negative effects on your community and the environment	WR
67	Work with a partner.	WR
68	Create a + and - chart for the different ways to generate electricity.	WR
69	There are two major categories for classifying types of energy resources — renewable and non-renewable.	WR
70	A renewable energy resource can be used over and over.	WR
71	It is never used up	WR
72	Hydroelectricity, wind, and solar energy are examples of renewable energy resources.	WR
73	A non-renewable energy resource can only be used once.	WR
74	Coal is an example of non-renewable energy source.	WR
75	Hydroelectric dams create electricity by having a flow of water turn a generator.	R
76	A generator is a device that can create electricity, if it can be made to spin.	WR
77	The water needed to spin the generator usually comes from a river, that has been blocked by a dam.	WR
78	The water that is blocked by the dam is called a reservoir.	WR
79	This reservoir can be used for both recreational purposes and farm irrigation.	R
80	It ensures that there will always be water available to turn the generators and make electricity.	R
81	Electrical generators operate without creating air pollution and are reasonably cheap to operate.	R
82	Unfortunately, the large dams needed for the production of	WR

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	electricity are expensive to build.	
83	For each dam there is only a limited number of spots where they can be built.	WR
84	Once the dam is built, the reservoirs can destroy local ecosystems and flood agricultural land.	WR
85	One characteristic of hydroelectric dams is the transmission lines needed to carry the electricity from the dams to cities in Canada.	R
86	These transmission lines are usually long and expensive to build.	WR
87	Solar energy uses the energy from the sun and transforms it into other forms of energy.	WR
88	For example, the sun could be used to heat water for showers, washing dishes, and other household needs.	R
89	This is called passive solar heating.	WR
90	Active solar heating occurs when solar energy is used in conjunction with other electrical devices.	WR
91	Solar energy is available everywhere the sun shines.	WR
92	It is simple to use.	WR
93	Devices such as solar panels can be added to houses quite easily.	WR
94	There is no pollution created when solar energy is used to generate electricity.	WR
95	However, using solar energy to generate electricity does have several problems.	WR
96	The sun only shines for part of the day, and some days may be cloudy.	R
97	A solar cell used to generate electricity is quite expensive.	WR
98	Over time it is expected that costs will get cheaper.	WR
99	Generating solar energy takes up a lot of space.	WR
100	Most solar-generated electricity is produced on a small scale	R

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	because it would take a large area of land to produce a vast amount of electricity	
101	Collecting energy from the wind requires a windmill, turbine, or blade to catch and turn in the wind.	R
102	There are many different types of devices that can be used.	WR
103	Four of the more common types are pictured here.	WR
104	Each kind has been used in Canada, but the multiblade and two- or three-blade high speed rotors are the most common.	WR
105	Wind is free, renewable, and pollution free.	WR
106	Windmills can be set up faster than dams or coal power plants.	WR
107	Unfortunately wind speed is variable, turbines break down, birds can be killed flying into them, and the electricity is expensive to generate.	R
108	About 50 years ago a process to control the breakdown of the smallest units of matter was discovered.	WR
109	During the breakdown of matter, energy was given off.	R
110	This energy can be harnessed and used to produce electricity.	R
111	The most common material used for this process is uranium.	WR
112	The production of electricity occurs in a nuclear power plant.	WR
113	Canadian scientists and engineers have developed one type of nuclear power plant called the Canada Deuterium-Uranium reactor, or CANDU reactor.	WR
114	The CANDU reactor converts the energy given off from the breakdown of matter to heat water into steam.	R
115	The steam is then used to spin generators to create electricity.	R
116	The cost of uranium fuel is relatively cheap.	WR
117	Uranium can be found in many parts of the world.	WR
118	Nuclear power plants do not produce air pollution that cause	R

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	environmental concerns like acid rain.	
119	For many countries, the use of nuclear energy is an option if no other forms of energy production are available.	WR
120	The use of nuclear energy requires several considerations.	WR
121	There are only about another 100 years of uranium supply left for use.	WR
122	A nuclear power plant is expensive to build.	WR
123	A nuclear power plant functions for 30 to 50 years before it must be dismantled.	WR
124	The waste from a nuclear power plant is highly radioactive and must be carefully handled and stored for a long period of time.	WR
125	While the chance of a nuclear accident is low, any major incident would have an impact on the whole country.	WR
126	Coal is mined in all the provinces of Canada, except Manitoba and Quebec.	WR
127	Once mined from the ground, it is commonly burned to make electricity and steel.	R
128	In fact, almost half of the world's electricity comes from burning coal.	WR
129	To generate electricity, coal is burned to heat water into steam.	R
130	The steam is then used to spin generators to create electricity.	R
131	This is similar to the generators in dams, except that in dams water is used instead of steam.	WR
132	Using coal for making electricity is relatively cheap, and the world has a large quantity of coal available.	WR
133	An added benefit of using coal is that other products can be made from it.	WR
134	These products include fertilizers, paints, and plastics.	WR

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135	However, using coal has certain disadvantages too.	WR
136	Mining coal can be dangerous and disruptive to the environment.	WR
137	Burning coal can create air and water pollution.	WR
138	As coal is non-renewable, it will eventually be used up, or be too expensive to mine.	WR
139	Light bulbs, wires, batteries, and switches.	WR
140	These are all important in making electrical circuits.	WR
141	But, how do you get them to work together?	WR
142	There is only one way to find out.	WR
143	Try it!	WR
144	You are now an official investigator of electrical circuits.	WR
145	As with any good investigator, it is important to make sure that everyone you work with uses the same terms and language.	WR
146	Working with electrical circuits is no different.	WR
147	You may have noticed that you and your partner sometimes use different words for the same thing.	WR
148	This could get very confusing - fast!	WR
149	To help reduce confusion, there are terms and symbols connected with each piece of electrical equipment.	WR
150	As you read this lesson, you will keep a list of terms and symbols that are new to you or your partner on an electrical place mat.	WR
151	The electrical place mat should be a large piece of paper between you and your partner.	WR
152	As you see a term or symbol that is new to you, write it down anywhere on the paper.	WR
153	Any material that can carry electricity is conducting material.	WR

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154	Usually the common term for this material is called a wire.	WR
155	A wire is drawn in either a straight line or at a right angle if the wire changes direction.	WR
156	An electrical device is anything that requires electricity to operate.	WR
157	A radio, television, computer, walkman, light bulb or LED are all examples of electrical devices.	WR
158	For your activity, light bulbs and LEDs will almost always be used.	WR
159	All circuits need some type of energy source.	WR
160	The energy source for the circuits you will use is a battery or electric cell.	WR
161	It is called a primary cell if it cannot be recharged, and a secondary cell if it can be recharged.	WR
162	There are many different types of switches available.	WR
163	Each switch can create a different way to control an electrical device.	WR
164	For example, think of a light switch.	WR
165	This kind of switch is called a toggle switch.	WR
166	Switches that can perform a similar function are called a slide switch and a popper switch.	WR
167	Can you think of an electrical device where you have seen these switches working?	WR
168	Switches can also be used to control electrical devices by detecting, pressure, heat, and light.	R
169	The reed switch works when two wires are pressed together to complete a circuit.	R
170	This switch could be used under a doormat and be connected to the doorbell.	R
171	When someone steps on the mat, the doorbell rings.	R

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172	The tilt switch can be found in a thermostat.	WR
173	As the temperature goes down, the bi-metal strip bends and moves the switch to the right.	R
174	The mercury rolls to the right and connects the two wires.	R
175	The heater turns off.	WR
176	The photoelectric cell detects light and produces electricity.	WR
177	This type of cell is also used in solar energy.	WR
178	When there is light, the circuit is on; when it is dark, the circuit is off.	R
179	For your activity, the symbol for a switch is:	WR
180	Use these symbols to draw your circuits.	WR
181	Anyone who has studied electricity will be able to read them.	WR
182	Make sure that your work is neat and clearly labelled.	WR
183	Now that you know about the key features of an electrical circuit, you can investigate different types of circuits.	WR
184	In the Light Up the Class activity, you started to build electrical circuits to solve a particular problem.	WR
185	In the previous activity, you identified the key features of an electrical circuit.	WR
186	Now you will use your understanding of electrical circuits to build two types of circuits.	WR
187	They are a series circuit and a parallel circuit.	WR
188	All circuits can be classified as one of these two types.	WR
189	Make sure your hands are dry when touching electrical appliances and switches.	WR
190	When wiring a parallel circuit, make sure it is disconnected from the battery to prevent shock.	WR
191	There are so many uses for electricity. But what happens when	WR

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	something breaks down?	
192	Maybe your television doesn't have sound when it is turned on or your hair dryer doesn't blow any hot air.	WR
193	What do you do?	WR
194	Many people take their broken appliances to a repair shop or have a technician come to the home.	WR
195	When an electrical appliance is sent for repairs, the technician has to determine what is wrong.	WR
196	This process is called troubleshooting.	WR
197	Troubleshooting requires a person to ask a series of yes or no questions to determine the problem.	WR
198	Once the problem is known, it can be fixed.	WR
199	You are going to have an opportunity to develop your troubleshooting skills, and then a chance to try and solve an electrical problem.	WR
200	In previous activities you have observed batteries turning chemical energy to electrical energy which was transformed into sound, light, and motion energy.	WR
201	You have also observed that materials like salt water and metals can conduct electricity.	WR
202	You can also provide an example of electricity moving.	WR
203	For example, when you used your electrical tester and the metal spoon, electricity flowed from the battery, through the wires and the spoon to light the LED and then back to the battery.	R
204	In some situations, electricity does not move.	WR
205	This is called static electricity.	WR
206	Can you think of any examples of static electricity?	WR
207	Share your examples with a partner.	WR

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208	Make a list with two columns.	WR
209	In the first column list the examples which you both agree are static electricity.	WR
210	In the second column list the examples which you and your partner are not sure are static electricity.	WR
211	The following advertisement about Magical Balloons was found on the Internet.	WR
212	Your task is to determine if your class should purchase a Magical Balloon.	WR
213	You will need to collect evidence to support your decision.	WR
214	Try to prove or disprove the claims in the advertisement by reproducing the "magical qualities" of the balloon.	WR
215	The Magical Balloon is an example of static electricity.	WR
216	Static electricity stays in one place.	WR
217	In this case, it stays on the balloon.	WR
218	Your investigation showed that static electricity can cause objects to move or stick to one another.	WR
219	Have you ever played with magnets?	WR
220	Maybe you have seen one in a toy or a game or at school.	WR
221	They come in different shapes, sizes, and colours.	WR
222	They can pick up things, hold on to things, and move objects away.	WR
223	Sometimes magnets stick together or move away from each other.	WR
224	Magnetism is the force around a magnet.	WR
225	It is strongest at a magnet's poles.	WR
226	The poles are labelled N and S. N is for the North Pole of the magnet, and S is for the South Pole of the magnet.	WR

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227	What would happen if you put the N of one magnet near the N of another magnet?	WR
228	What other way could you place two magnets so they would push away from each other?	WR
229	Which way could you place two magnets so they would stick together?	WR
230	Magnets can exert a force on an object and make it move without touching it.	WR
231	Some people may have called this magic a long time ago.	WR
232	But you can observe this effect by using a bar magnet and some iron filings.	WR
233	Place a piece of paper on your desk.	WR
234	Sprinkle some iron filings on the paper.	WR
235	Stick the magnet underneath the desk.	WR
236	Move the magnet around.	WR
237	Can you see the iron filings move?	WR
238	This is an example of magnetic force acting on the iron filings without actually touching the iron filings.	WR
239	Let's look at another example of magnetic force acting on an object at a distance.	WR
240	Did you know there are different kinds of magnets?	WR
241	Some magnets are permanent.	WR
242	These magnets stay magnetized for long periods of time.	WR
243	Other magnets are considered temporary.	WR
244	They can turn their magnetism on and off.	WR
245	For example, a motor, a fire alarm bell, and a telephone all require temporary magnets called electromagnets	WR
246	In the last activity, you learned that a compass needle moved	WR

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	when electricity moved through the wire.	
247	The electricity acted like a temporary magnet.	WR
248	As soon as the electricity was off, the compass returned to its normal position.	WR
249	You are going to build an electromagnet.	WR
250	By the end of the activity, you should be able to describe its characteristics.	WR
251	Before you start, discuss with your partner how to get a paper clip and an iron nail to stick together.	WR
252	Talking on the phone, watching television, and sending an e-mail.	WR
253	What do these activities have in common?	WR
254	If you said they are all forms of communication, you would be right!	WR
255	These forms of communication also rely on electricity.	WR
256	Before electricity, people had difficulty communicating across great distances.	WR
257	Sometimes it took weeks or months to get a message from Halifax to Vancouver.	WR
258	Now you can talk to almost anyone in the world instantly.	WR
259	How does this happen?	WR
260	Let's start with a Canadian discovery.	WR
261	"To be or not to be" are words spoken by Hamlet, the hero in the play *Hamlet,* written by William Shakespeare.	WR
262	They were also the first words spoken on a long distance telephone call from the Ontario inventor, Alexander Graham Bell.	WR
263	It was the summer of 1876.	WR

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264	Bell used, among other things, a thin sheet of metal, a coil of wire wrapped around a magnet, and a battery to create a telephone.	WR
265	This device was able to convert sound into electricity, and back to sound.	WR
266	Now thousands of kilometres can separate where the sound was made and where it was heard.	WR
267	Canadians can now talk to each other instantly rather than wait weeks for a letter.	WR
268	Did you know that the first owner of a telephone in Canada was Prime Minister Alexander Mackenzie?	WR
269	He used the phone to talk to the Governor-General in 1877.	WR
270	When phones were first invented the person using the phone had to move the receiver between the ear and the mouth.	WR
271	Sometimes people got confused and talked when they should have listened or listened when they should have talked!	WR
272	In 1878, Cyril Duquet of Quebec designed a phone receiver to have both an ear and voice piece like the phones of today.	WR
273	Canadians continued to be involved in inventing devices that used electricity to send signals over great distances.	WR
274	The first wireless voice message was sent by Quebec inventor Reginald A. Fessenden in 1900.	WR
275	His first message only travelled 2 km.	WR
276	In 1906, the world started to communicate by sending electronic signals through the atmosphere.	WR
277	Using a microphone, Fessenden's voice was converted to a radio signal that could be sent and received at another location.	R
278	The key to the operation?	WR
279	All of his devices required electricity.	WR

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280	In 1924, Sir William Stephenson of Manitoba invented a method of sending pictures for newspapers over phone lines.	WR
281	In 1927, Edward Samuels Rogers of Ontario made the first radio that could be plugged into a wall outlet.	WR
282	In 1942, Donald L. Hings of British Columbia invented the portable transceiver, or Walkie-Talkie.	WR
283	In 1972, Anik 1 was launched.	WR
284	It was the world's first geostationary communications satellite.	WR
285	This satellite was the first one to allow ordinary people to communicate with each other by having their voices sent electronically through space.	WR
286	In 1987, when Anita Luszszak was 15 years old, she developed a pulsating generator that used less energy to generate electrical power than the conventional power generators.	WR
287	The Albertan student won a gold medal at an international competition for inventors.	WR
288	In 1998, electric cars have Canadian inventors very busy.	WR
289	Pierre Couture of Quebec is developing a car that has four electric motors on each wheel of the car.	WR
290	Ballard Power Systems Inc. of British Columbia is developing a fuel cell that will power the electric cars of the future.	WR
291	From satellites to fiber optic communications, Canadians are leaders in the world of global communications.	WR
292	Using electricity, Canadians have found many ways to send signals throughout the world.	WR
293	Electricity is something most of us assume will always be available.	WR
294	However, in many countries electricity is not as common.	WR

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295	In Canada you can flip a switch and light a room, or turn on a television to watch a show.	WR
296	Many people in other countries do not have this same lifestyle.	WR
297	You are going to have an opportunity to compare the different energy lifestyles between a Canadian and a Mongolian student.	WR
298	Before you make an energy comparison between two countries, you will need to have a method on which to base your comparison on.	WR
299	The amount of electricity used by an appliance is measured in a unit called kilowatt hours, or kWh.	WR
300	A kWh costs about five cents.	WR
301	A television that uses 1 kWh would cost five cents for every hour that it is turned on.	WR
302	A television turned on for three hours would cost fifteen cents.	WR
303	The table shows approximately how many kilowatt hours an electrical appliance uses in a typical day.	WR
304	Nine-year old Batsuury climbs out of bed and gets ready for school.	WR
305	She can see her mom and dad are already up and they have turned on the light bulb.	WR
306	Living in a one-room tent allows her to see her dad starting a fire in the stove.	WR
307	The stove also heats the tent.	WR
308	Her mom starts breakfast as she listens to the daily news report on their black-and-white television.	WR
309	Her mom asks her to go outside to the ice box and bring in the milk.	WR
310	As Batsuury goes outside the tent, or *ger,* she barely notices the	WR

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	sun.	
311	There is a haze in the air created by the coal-generating power plant.	WR
312	As she brings in the milk, her mom plugs in the electric kettle to make tea for the family.	WR
313	Batsuury lives with her mother, father, brother, sister, aunt, and cousin.	WR
314	While breakfast is being made, she puts on her school uniform.	WR
315	Another day has begun.	WR
316	Halfway around the world, Jennifer is getting ready to go to a surprise birthday party.	WR
317	She and her dad have spent the afternoon baking a cake.	WR
318	Her brother, Rhys, wasn't interested in helping, so he is playing video games on the colour television.	WR
319	Her mom is at work.	WR
320	As the cake is baking, Jennifer cleans the kitchen and by accident drops the leftover cake batter.	WR
321	The batter lands everywhere, including on her clothes.	WR
322	Luckily, she has time to take a shower and change her clothes before the party.	WR
323	While she blow-dries her hair, she listens to her favourite music on her clock radio.	WR
324	When she is ready to go, she grabs the cake from the refrigerator and thanks her dad for helping her.	WR
325	She also promises to clean out the dishwasher when she gets home.	WR
326	The amount of electricity used by Canadians when compared to other countries is considered quite high.	WR
327	In 1996, Canada was the sixth largest user of electricity in the	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	world.	
328	One of the ways to reduce our electricity use is to conserve it when possible.	WR
329	If everyone conserves a small amount of electricity, this can add up to huge savings.	WR
330	Join your partner or small group.	WR
331	Brainstorm all the different ways you can think of to save electricity at home and at school.	WR
332	When your list is complete, share it with the class.	WR
333	In your group, design an action plan that will identify five ways to conserve electricity.	WR
334	You may want to use the ideas from your list.	WR
335	For example, you may decide to turn out the light in your bedroom when you are not there.	WR
336	This may save 1 kWh per month.	WR
337	If everyone in Canada did this, we would save $1.5 million a month!	WR
338	Have you ever wondered how inventions are made?	WR
339	Sometimes people have an idea and other times they just try something and see how it works.	WR
340	Either way, inventors are willing to take risks and try things no one else has ever done.	WR
341	Sometimes the reward for your invention can last longer than a lifetime.	WR
342	An example of this is Elijah McCoy, the inventor of the automatic oil cup and the lawn sprinkler.	WR
343	He was born in Ontario in 1844 after his family fled to Canada to escape slavery in the United States.	WR
344	His inventions were so well received people referred to them as the	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	"Real McCoy."	
345	This term is still used today to indicate an object that is the actual object and not an imitation.	WR
346	You have developed an Electric Timeline to illustrate important inventors or inventions in the area of electricity.	WR
347	Now it is time to add your name and invention to the Timeline!	WR
348	You will design an electrical device that will send a signal to your friend at the other end of the room.	WR
349	Remember the following:	WR
350	You should be able to send the signal at any time.	WR
351	You should be able to repeat the signal.	WR
352	You should not disturb others around you, when you send the signal.	WR
353	Now it's time to show how much you have learned about electricity.	WR
354	Read over what your tasks are, and talk to your teacher if you are unclear about what to do.	WR
355	You have been given the task of designing an automatic electrical light system for a home workshop.	WR
356	The machines in the workshop are very noisy, so the door must be closed when the owner of the house is in the workshop.	R
357	Since she often carries materials in and out of the workshop, it would be helpful to have an automatic light switch.	WR
358	The light must go on when the door closes and go off when the door opens.	WR
359	Also, there are two lights in the room that must work together.	WR
360	As a safety measure, the design should ensure that one light bulb	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	will still work if the other goes out.	
361	You may use any piece of equipment discussed in this unit to design your automatic light switch.	WR
362	The owner would like a neat, labelled diagram and a description explaining how the electrical system will operate.	WR
363	She will also need a list of materials to be purchased to build the electrical light system.	WR
364	Now check your work.	WR
365	My work contains a diagram, a description, and a list of materials. Each is complete.	WR
366	My diagram uses appropriate symbols and is correctly labelled.	WR
367	In my design, the light goes off and on automatically when the door opens and closes.	WR
368	My design contains two lights that work independently.	WR
	-----GLOSSORY GIVEN IN THE NEXT LINES ------	*GLOSSARY*
369	active solar heating solar energy used in conjunction with other electrical devices to create heat	WR
370	battery a number of electric cells connected together that supply energy	WR
371	chemical energy the energy stored in the bonds between the smallest units of matter	WR
372	circuit an arrangement of electrical devices that allows electricity to flow through conductors	WR
373	coal a black mineral that can be burned to make electricity or used to make chemicals; a non-renewable resource	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
374	conductor a material that allows electricity to pass through it	WR
375	electrical energy produced by a current flowing through a wire or other object	R
376	electricity a form of energy that can flow through conductors	R
377	electromagnets the temporary magnets made of an iron bar with coils of wire around it; they act as magnets when electricity flows through the wire coils	R
378	fiber optic communications communication by means of light signals along thin glass fibers	R
379	generator a device that creates electricity from the mechanical energy of the rotation of the centre of the generator	R
380	insulator a material that does not allow electricity to pass through it	WR
381	kilowatt hours (kWh) a unit of measure of the amount of electricity	WR
382	light bulb the common name for an electric lamp that produces light by heating a thin wire thread to a very high temperature	R
383	light-emitting diode (LED) a small type of light bulb	WR
384	magnetic force the force that acts between two magnets by pulling them together or pushing them away from each other	R
385	magnetic poles the two ends of a magnet where the magnetic force is strongest	WR
386	magnetism the force around a magnet	WR
387	non-renewable an energy resource that can only be used once and cannot be replaced	WR
388	nuclear energy the energy produced by the breakdown of the smallest units of matter; the heat produced turns the water into steam, which drives the generators in nuclear power plants	R
389	parallel circuit a path of electrical current that has more than one	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	loop in the circuit	
390	passive solar heating the energy from the sun used to create heat	WR
391	popper switch a switch that can be pushed to turn electricity off and on	R
392	primary cell a non-rechargeable device	WR
393	prosthesis an artificial body part	WR
394	radioactive a property of substances that give off energy when their smallest units of matter decay	R
395	renewable an energy resource that can be used over and over or replaced	WR
396	reservoir the water that is blocked by a dam	WR
397	secondary cell a rechargeable device	WR
398	series circuit a path of electrical current that passes through each device in the circuit, one after another; a path that has one loop	WR
399	slide switch a switch used to turn electricity off and on by moving a slider back and forth	R
400	solar energy the energy from the sun, either light or heat	WR
401	static electricity electricity that does not move	WR
402	toggle switch a switch used to turn electricity off and on using a lever	R
403	troubleshooting the process of discovering and eliminating causes of trouble	R
404	uranium a radioactive metal used in nuclear power plants	WR
405	Walkie-Talkie portable transceiver invented by Canadian Donald L. Hings in 1942	WR
406	wire a thin thread of metal that can carry electricity	WR

Appendix 3B

Paragraph analysis (CT)

The columns with 1,2,3,4 indicate the following:

(1) discusses daily life use of electricity, electricity resources; (2) asks readers to ‘think about’, ‘ imagine’, ‘don’t you think’, asks questions, asks to identify, asks to compare; (3) explains something using reason(s); (4) Includes numeric values (2 km, 1000 kWh, 1888 AD)

No.	**Paragraphs**	1	2	3	4
1	Electricity. It's all around you. It’s invisible. It can be used for many purposes such as listening to music, finding your way down a dark path, or talking to a relative in another part of Canada. You will participate in an electric adventure as you learn about electricity.	x			
2	Electricity is everywhere! It can be found in your house, your school, at the soccer field, or baseball diamond. Use the illustration on these two pages. Identify and list as many examples as you can of electricity being used.		x		
3	If you want to operate a portable radio or walkman, you need batteries. These batteries can be purchased at most stores. Sometimes they are rechargeable. This has not always been the case. Imagine yourself back in the past, before television, cars, and light bulbs. You are now 200 years back in time. Canada will not become a country for another 50 years. There were no fridges to keep the food cold like the fridges we use today. This is because there was no electricity. What do you think people used to keep their food cold? Draw what you think was used to keep food cold. Review the drawing of your fridge with others in your class.	x	x		
4	Review the drawing of your fridge with others in your class. Aren't you glad that we have access to electrical devices like fridges, ovens, and computers? How did humans discover and harness electricity? Believe it or not, it all started with a frog's leg, a brass hook, an iron railing, and a lightning storm.		x		

No.	**Paragraphs**	1	2	3	4
5	Luigi Galvani was an Italian scientist and a medical doctor. In 1786, while examining a dead frog, he noticed that a spark could make the frog's leg move, when two different metals were touching the frog's leg. He was curious as to why this happened. He wondered if he could repeat the observation under different conditions. Galvani guessed that the spark traveled from one metal, through the frog's muscle, and then into the other metal. While this later turned out to be the correct guess, he didn't know how this could happen. But he was determined to find out.				X
6	As the next lightning storm approached, Galvani used a brass hook to hold the frog's muscle and attached this hook to an iron railing. He knew the storm would create a spark. The spark could then travel between the brass hook and iron railing to make the muscle move. As the rain came down and the lightning flashed around him, he observed and recorded the changes to the muscle. He noticed that the muscle moved! Using his observations, he proposed that the muscle moved because of electricity. While there was much excitement in his town and country about the discovery of electricity, it was only the beginning of the investigation for scientists all around the world.				
7	If a person has a leg or arm amputated, it is usually replaced with a device called prosthesis, or artificial leg or arm. Today, scientists are investigating ways to make artificial legs or arms move. Just like Galvani's experiments, they are using electricity to make an arm move up and down or a leg bend at the knee.	x			
8	In 1796, after Galvani's muscle experiment, another scientist from Italy, Alessandro Volta, wondered if he could make electricity rather than observe it. Instead of using a frog's muscle, Volta used different liquids. He placed these liquids in bowls and then connected the bowls with pieces of metal.				X
9	Volta discovered that when he used saltwater in the bowl and connected the bowls with copper and zinc metal, he could produce a spark. This was very exciting because he designed a chemical cell which would soon become a battery!				

No.	**Paragraphs**	1	2	3	4
10	In 1967, then 17-year-old Richard Keefer of Ontario invented a battery that could run on garbage! The battery lasted longer than store bought batteries and cost about the same price.				X
11	You now know about the discovery of electricity and batteries by scientists over 200 years ago. It is time for you to explore the characteristics of electricity. Before you start, write down your thoughts about the following statements and make sure to include an explanation if you can. Can you make electricity with a fruit and six cents? Can electricity make objects move? Can electricity go through a toothpick, fork, or straw?		x		X
12	Before you make a decision, it is important to have all the information that will help you make that decision. Would you buy a game for your friend without knowing if she would like it? Would you go on a trip without making sure you knew how to get there and where you would stay?		x		
13	You can find some of this information by asking someone. Other information needs to be researched. When you do your research, it is important to keep all the information organized. One method of organizing information is in a + and - chart. This type of chart allows you to identify the positive and negative characteristics of the particular subject you are studying. Look at the chart. This is an example of how one student listed the information using the + and - to help him decide if he should buy a bicycle.		x		
14	A + and - chart can also be used for collecting science information. You are going to read about five different ways to generate electricity. Each way has positive and negative effects on your community and the environment Work with a partner. Create a + and - chart for the different ways to generate electricity.		x		

No.	**Paragraphs**	1	2	3	4
15	There are two major categories for classifying types of energy resources — renewable and non-renewable. A renewable energy resource can be used over and over. It is never used up. Hydroelectricity, wind, and solar energy are examples of renewable energy resources. A non-renewable energy resource can only be used once. Coal is an example of non-renewable energy source.	x			
16	Hydroelectric dams create electricity by having a flow of water turn a generator. A generator is a device that can create electricity, if it can be made to spin. The water needed to spin the generator usually comes from a river, that has been blocked by a dam. The water that is blocked by the dam is called a reservoir. This reservoir can be used for both recreational purposes and farm irrigation. It ensures that there will always be water available to turn the generators and make electricity. Electrical generators operate without creating air pollution and are reasonably cheap to operate.			x	
17	Unfortunately, the large dams needed for the production of electricity are expensive to build. For each dam there is only a limited number of spots where they can be built. Once the dam is built, the reservoirs can destroy local ecosystems and flood agricultural land. One characteristic of hydroelectric dams is the transmission lines needed to carry the electricity from the dams to cities in Canada. These transmission lines are usually long and expensive to build.	x			
18	Solar energy uses the energy from the sun and transforms it into other forms of energy. For example, the sun could be used to heat water for showers, washing dishes, and other household needs. This is called passive solar heating. Active solar heating occurs when solar energy is used in conjunction with other electrical devices.	x			

No.	**Paragraphs**	1	2	3	4
19	Solar energy is available everywhere the sun shines. It is simple to use. Devices such as solar panels can be added to houses quite easily. There is no pollution created when solar energy is used to generate electricity.	x			
20	However, using solar energy to generate electricity does have several problems. The sun only shines for part of the day, and some days may be cloudy. A solar cell used to generate electricity is quite expensive. Over time it is expected that costs will get cheaper. Generating solar energy takes up a lot of space. Most solar-generated electricity is produced on a small scale because it would take a large area of land to produce a vast amount of electricity.	x			
21	Collecting energy from the wind requires a windmill, turbine, or blade to catch and turn in the wind. There are many different types of devices that can be used. Four of the more common types are pictured here. Each kind has been used in Canada, but the multiblade and two- or three-blade high speed rotors are the most common.	x			
22	Wind is free, renewable, and pollution free. Windmills can be set up faster than dams or coal power plants. Unfortunately wind speed is variable, turbines break down, birds can be killed flying into them, and the electricity is expensive to generate.	x			
23	About 50 years ago a process to control the breakdown of the smallest units of matter was discovered. During the breakdown of matter, energy was given off. This energy can be harnessed and used to produce electricity. The most common material used for this process is uranium. The production of electricity occurs in a nuclear power plant. Canadian scientists and engineers have developed one type of nuclear power plant called the Canada Deuterium-Uranium reactor, or CANDU reactor.			x	X
24	The CANDU reactor converts the energy given off from the breakdown of matter to heat water into steam. The steam is then used to spin generators to create electricity.			x	

No.	**Paragraphs**	1	2	3	4
25	The cost of uranium fuel is relatively cheap. Uranium can be found in many parts of the world. Nuclear power plants do not produce air pollution that cause environmental concerns like acid rain. For many countries, the use of nuclear energy is an option if no other forms of energy production are available.	x		x	
26	The use of nuclear energy requires several considerations. There are only about another 100 years of uranium supply left for use. A nuclear power plant is expensive to build. A nuclear power plant functions for 30 to 50 years before it must be dismantled. The waste from a nuclear power plant is highly radioactive and must be carefully handled and stored for a long period of time. While the chance of a nuclear accident is low, any major incident would have an impact on the whole country.	x			X
27	Coal is mined in all the provinces of Canada, except Manitoba and Quebec. Once mined from the ground, it is commonly burned to make electricity and steel. In fact, almost half of the world's electricity comes from burning coal. To generate electricity, coal is burned to heat water into steam. The steam is then used to spin generators to create electricity. This is similar to the generators in dams, except that in dams water is used instead of steam.	x		x	
28	Using coal for making electricity is relatively cheap, and the world has a large quantity of coal available. An added benefit of using coal is that other products can be made from it. These products include fertilizers, paints, and plastics.	x			
29	However, using coal has certain disadvantages too. Mining coal can be dangerous and disruptive to the environment. Burning coal can create air and water pollution. As coal is non-renewable, it will eventually be used up, or be too expensive to mine.	x			
30	Light bulbs, wires, batteries, and switches. These are all important in making electrical circuits. But, how do you get them to work together? There is only one way to find out. Try it!	x	x		

No.	**Paragraphs**	1	2	3	4
31	You are now an official investigator of electrical circuits. As with any good investigator, it is important to make sure that everyone you work with uses the same terms and language. Working with electrical circuits is no different. You may have noticed that you and your partner sometimes use different words for the same thing. This could get very confusing - fast!				
32	To help reduce confusion, there are terms and symbols connected with each piece of electrical equipment.				
33	As you read this lesson, you will keep a list of terms and symbols that are new to you or your partner on an electrical place mat. The electrical place mat should be a large piece of paper between you and your partner. As you see a term or symbol that is new to you, write it down anywhere on the paper.		x		
34	Any material that can carry electricity is conducting material. Usually the common term for this material is called a wire. A wire is drawn in either a straight line or at a right angle if the wire changes direction.				
35	An electrical device is anything that requires electricity to operate. A radio, television, computer, walkman, light bulb or LED are all examples of electrical devices.	x			
36	For your activity, light bulbs and LEDs will almost always be used.	x			
37	All circuits need some type of energy source. The energy source for the circuits you will use is a battery or electric cell. It is called a primary cell if it cannot be recharged and a secondary cell if it can be recharged.	x			
38	There are many different types of switches available. Each switch can create a different way to control an electrical device. For example, think of a light switch. This kind of switch is called a toggle switch. Switches that can perform a similar function are called a slide switch and a popper switch. Can you think of an electrical device where you have seen these switches working?		x		
39	Switches can also be used to control electrical devices by detecting, pressure, heat, and light.	x			

No.	**Paragraphs**	1	2	3	4
40	The reed switch works when two wires are pressed together to complete a circuit. This switch could be used under a doormat and be connected to the doorbell. When someone steps on the mat, the doorbell rings.	x			
41	The tilt switch can be found in a thermostat. As the temperature goes down, the bi-metal strip bends and moves the switch to the right. The mercury rolls to the right and connects the two wires. The heater turns off.			x	
42	The photoelectric cell detects light and produces electricity. This type of cell is also used in solar energy. When there is light, the circuit is on; when it is dark, the circuit is off.	x			
43	For your activity, the symbol for a switch is: Use these symbols to draw your circuits. Anyone who has studied electricity will be able to read them. Make sure that your work is neat and clearly labeled.		x		
44	Now that you know about the key features of an electrical circuit, you can investigate different types of circuits. In the Light Up the Class activity, you started to build electrical circuits to solve a particular problem. In the previous activity, you identified the key features of an electrical circuit. Now you will use your understanding of electrical circuits to build two types of circuits. They are a series circuit and a parallel circuit. All circuits can be classified as one of these two types.		x		
45	Make sure your hands are dry when touching electrical appliances and switches. When wiring a parallel circuit, make sure it is disconnected from the battery to prevent shock.				
46	There are so many uses for electricity. But what happens when something breaks down? Maybe your television doesn't have sound when it is turned on or your hair dryer doesn't blow any hot air. What do you do? Many people take their broken appliances to a repair shop or have a technician come to the home.		x		

No.	**Paragraphs**	1	2	3	4
47	When an electrical appliance is sent for repairs, the technician has to determine what is wrong. This process is called troubleshooting. Troubleshooting requires a person to ask a series of yes or no questions to determine the problem. Once the problem is known, it can be fixed. You are going to have an opportunity to develop your troubleshooting skills, and then a chance to try and solve an electrical problem.				
48	In previous activities you have observed batteries turning chemical energy to electrical energy which was transformed into sound, light, and motion energy. You have also observed that materials like salt water and metals can conduct electricity. You can also provide an example of electricity moving. For example, when you used your electrical tester and the metal spoon, electricity flowed from the battery, through the wires and the spoon to light the LED and then back to the battery. In some situations, electricity does not move. This is called static electricity. Can you think of any examples of static electricity? Share your examples with a partner. Make a list with two columns. In the first column list the examples which you both agree are static electricity. In the second column list the examples which you and your partner are not sure are static electricity.		x	x	
49	The following advertisement about Magical Balloons was found on the Internet. Your task is to determine if your class should purchase a Magical Balloon. You will need to collect evidence to support your decision. Try to prove or disprove the claims in the advertisement by reproducing the "magical qualities" of the balloon.				
50	The Magical Balloon is an example of static electricity. Static electricity stays in one place. In this case, it stays on the balloon. Your investigation showed that static electricity can cause objects to move or stick to one another.				

No.	**Paragraphs**	1	2	3	4
51	Have you ever played with magnets? Maybe you have seen one in a toy or a game or at school. They come in different shapes, sizes, and colours. They can pick up things, hold on to things, and move objects away. Sometimes magnets stick together or move away from each other. Magnetism is the force around a magnet. It is strongest at a magnet's poles. The poles are labeled N and S. N is for the North Pole of the magnet, and S is for the South Pole of the magnet. What would happen if you put the N of one magnet near the N of another magnet? What other way could you place two magnets so they would push away from each other? Which way could you place two magnets so they would stick together?		x		
52	Magnets can exert a force on an object and make it move without touching it. Some people may have called this magic a long time ago. But you can observe this effect by using a bar magnet and some iron filings. Place a piece of paper on your desk. Sprinkle some iron filings on the paper. Stick the magnet underneath the desk. Move the magnet around. Can you see the iron filings move? This is an example of magnetic force acting on the iron filings without actually touching the iron filings.		x		
53	Let's look at another example of magnetic force acting on an object at a distance.		x		
54	Did you know there are different kinds of magnets? Some magnets are permanent. These magnets stay magnetized for long periods of time. Other magnets are considered temporary. They can turn their magnetism on and off. For example, a motor, a fire alarm bell, and a telephone all require temporary magnets called electromagnets	x	x		
55	In the last activity, you learned that a compass needle moved when electricity moved through the wire. The electricity acted like a temporary magnet. As soon as the electricity was off, the compass returned to its normal position.				
56	You are going to build an electromagnet. By the end of the activity, you should be able to describe its characteristics. Before you start, discuss with your partner how to get a paper clip and an iron nail to stick together.		x		

No.	**Paragraphs**	1	2	3	4
57	Talking on the phone, watching television, and sending an e-mail. What do these activities have in common? If you said they are all forms of communication, you would be right! These forms of communication also rely on electricity.	x	x		
58	Before electricity, people had difficulty communicating across great distances. Sometimes it took weeks or months to get a message from Halifax to Vancouver. Now you can talk to almost anyone in the world instantly. How does this happen? Let's start with a Canadian discovery.		x		
59	"To be or not to be" are words spoken by Hamlet, the hero in the play *Hamlet,* written by William Shakespeare. They were also the first words spoken on a long distance telephone call from the Ontario inventor, Alexander Graham Bell. It was the summer of 1876. Bell used, among other things, a thin sheet of metal, a coil of wire wrapped around a magnet, and a battery to create a telephone. This device was able to convert sound into electricity, and back to sound. Now thousands of kilometers can separate where the sound was made and where it was heard. Canadians can now talk to each other instantly rather than wait weeks for a letter.	x			X
60	Did you know that the first owner of a telephone in Canada was Prime Minister Alexander Mackenzie? He used the phone to talk to the Governor-General in 1877.		x		X
61	When phones were first invented the person using the phone had to move the receiver between the ear and the mouth. Sometimes people got confused and talked when they should have listened or listened when they should have talked! In 1878, Cyril Duquet of Quebec designed a phone receiver to have both an ear and voice piece like the phones of today.	x			X

No.	**Paragraphs**	1	2	3	4
62	Canadians continued to be involved in inventing devices that used electricity to send signals over great distances. The first wireless voice message was sent by Quebec inventor Reginald A. Fessenden in 1900. His first message only traveled 2 km. In 1906, the world started to communicate by sending electronic signals through the atmosphere. Using a microphone, Fessenden's voice was converted to a radio signal that could be sent and received at another location. The key to the operation? All of his devices required electricity.		x		X
63	In 1924, Sir William Stephenson of Manitoba invented a method of sending pictures for newspapers over phone lines.				X
64	In 1927, Edward Samuels Rogers of Ontario made the first radio that could be plugged into a wall outlet.				X
65	In 1942, Donald L. Hings of British Columbia invented the portable transceiver, or Walkie-Talkie.				X
66	In 1972, Anik 1 was launched. It was the world's first geostationary communications satellite. This satellite was the first one to allow ordinary people to communicate with each other by having their voices sent electronically through space.	x			X
67	In 1987, when Anita Luszszak was 15 years old, she developed a pulsating generator that used less energy to generate electrical power than the conventional power generators. The Albertan student won a gold medal at an international competition for inventors.				X
68	In 1998, electric cars have Canadian inventors very busy. Pierre Couture of Quebec is developing a car that has four electric motors on each wheel of the car. Ballard Power Systems Inc. of British Columbia is developing a fuel cell that will power the electric cars of the future.	x			X
69	From satellites to fiber optic communications, Canadians are leaders in the world of global communications. Using electricity, Canadians have found many ways to send signals throughout the world.	x			

No.	**Paragraphs**	1	2	3	4
70	Electricity is something most of us assume will always be available. However, in many countries electricity is not as common. In Canada you can flip a switch and light a room, or turn on a television to watch a show. Many people in other countries do not have this same lifestyle. You are going to have an opportunity to compare the different energy lifestyles between a Canadian and a Mongolian student.	x	x		
71	Before you make an energy comparison between two countries, you will need to have a method on which to base your comparison on. The amount of electricity used by an appliance is measured in a unit called kilowatt hours, or kWh. A kWh costs about five cents. A television that uses 1 kWh would cost five cents for every hour that it is turned on. A television turned on for three hours would cost fifteen cents.	x			X
72	The table shows approximately how many kilowatt hours an electrical appliance uses in a typical day.	x			
73	Nine-year old Batsuury climbs out of bed and gets ready for school. She can see her mom and dad are already up and they have turned on the light bulb. Living in a one-room tent allows her to see her dad starting a fire in the stove. The stove also heats the tent. Her mom starts breakfast as she listens to the daily news report on their black-and-white television. Her mom asks her to go outside to the ice box and bring in the milk. As Batsuury goes outside the tent, or *ger,* she barely notices the sun. There is a haze in the air created by the coal-generating power plant. As she brings in the milk, her mom plugs in the electric kettle to make tea for the family. Batsuury lives with her mother, father, brother, sister, aunt, and cousin. While breakfast is being made, she puts on her school uniform. Another day has begun.	x			

No.	**Paragraphs**	1	2	3	4
74	Halfway around the world, Jennifer is getting ready to go to a surprise birthday party. She and her dad have spent the afternoon baking a cake. Her brother, Rhys, wasn't interested in helping, so he is playing video games on the colour television. Her mom is at work. As the cake is baking, Jennifer cleans the kitchen and by accident drops the leftover cake batter. The batter lands everywhere, including on her clothes. Luckily, she has time to take a shower and change her clothes before the party. While she blow-dries her hair, she listens to her favourite music on her clock radio. When she is ready to go, she grabs the cake from the refrigerator and thanks her dad for helping her. She also promises to clean out the dishwasher when she gets home.	x			
75	The amount of electricity used by Canadians when compared to other countries is considered quite high. In 1996, Canada was the sixth largest user of electricity in the world. One of the ways to reduce our electricity use is to conserve it when possible. If everyone conserves a small amount of electricity, this can add up to huge savings. Join your partner or small group. Brainstorm all the different ways you can think of to save electricity at home and at school. When your list is complete, share it with the class.	x	x		X
76	In your group, design an action plan that will identify five ways to conserve electricity. You may want to use the ideas from your list. For example, you may decide to turn out the light in your bedroom when you are not there. This may save 1 kWh per month. If everyone in Canada did this, we would save $1.5 million a month!	x	x		X

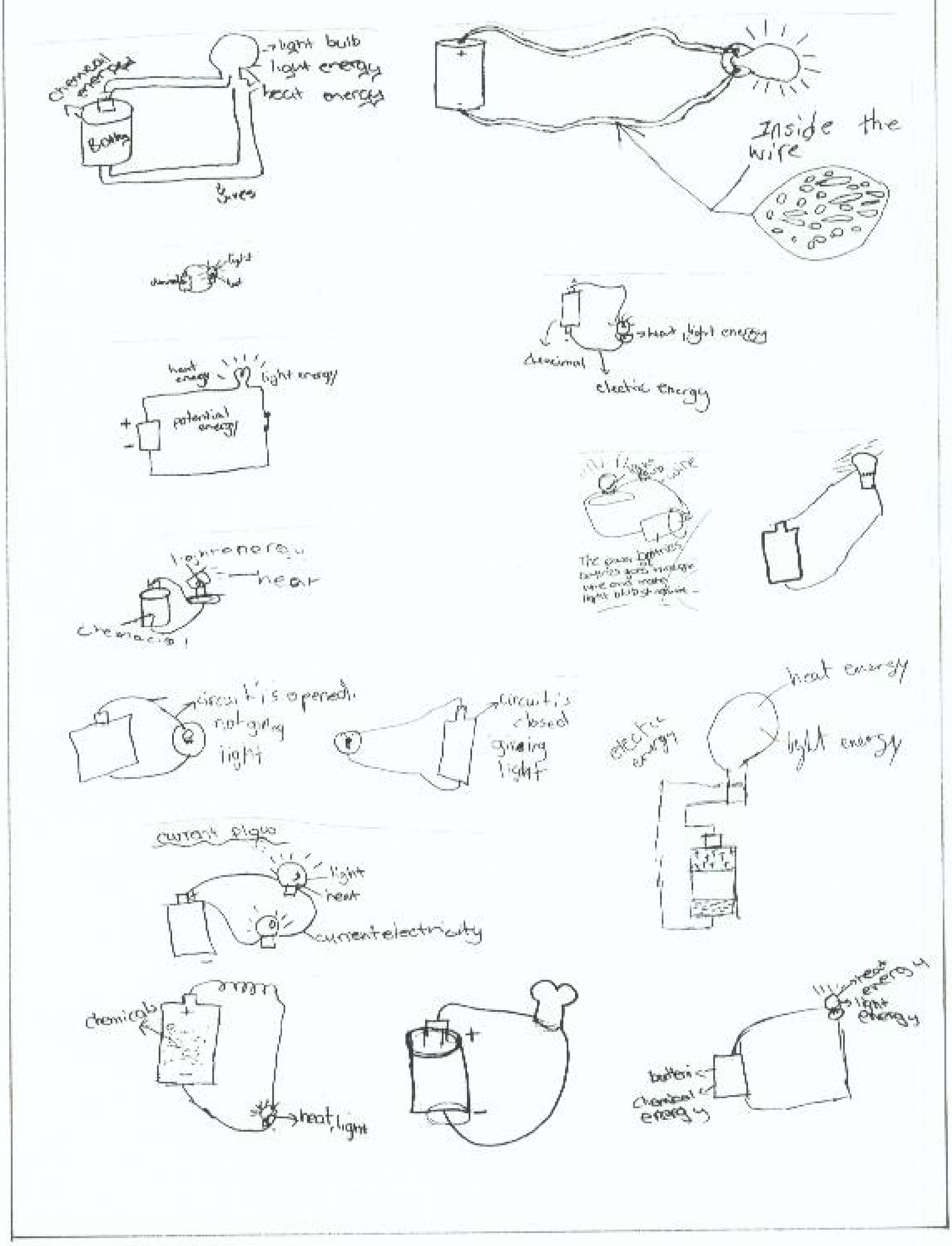
No.	**Paragraphs**	1	2	3	4
77	Have you ever wondered how inventions are made? Sometimes people have an idea and other times they just try something and see how it works. Either way, inventors are willing to take risks and try things no one else has ever done. Sometimes the reward for your invention can last longer than a lifetime. An example of this is Elijah McCoy, the inventor of the automatic oil cup and the lawn sprinkler. He was born in Ontario in 1844 after his family fled to Canada to escape slavery in the United States. His inventions were so well received people referred to them as the "Real McCoy." This term is still used today to indicate an object that is the actual object and not an imitation.		x		X
78	You have developed an Electric Timeline to illustrate important inventors or inventions in the area of electricity. Now it is time to add your name and invention to the Timeline!		x		
79	You will design an electrical device that will send a signal to your friend at the other end of the room. Remember the following: You should be able to send the signal at any time. You should be able to repeat the signal. You should not disturb others around you, when you send the signal.		x		
80	Now it's time to show how much you have learned about electricity. Read over what your tasks are, and talk to your teacher if you are unclear about what to do.		x		
81	You have been given the task of designing an automatic electrical light system for a home workshop. The machines in the workshop are very noisy, so the door must be closed when the owner of the house is in the workshop. Since she often carries materials in and out of the workshop, it would be helpful to have an automatic light switch. The light must go on when the door closes and go off when the door opens. Also, there are two lights in the room that must work together. As a safety measure, the design should ensure that one light bulb will still work if the other goes out.	x	x		

No.	**Paragraphs**	1	2	3	4
82	You may use any piece of equipment discussed in this unit to design your automatic light switch. The owner would like a neat, labeled diagram and a description explaining how the electrical system will operate. She will also need a list of materials to be purchased to build the electrical light system.		x		
83	Now check your work. My work contains a diagram, a description, and a list of materials. Each is complete. My diagram uses appropriate symbols and is correctly labeled. In my design, the light goes off and on automatically when the door opens and closes. My design contains two lights that work independently.		x		

Appendix 4

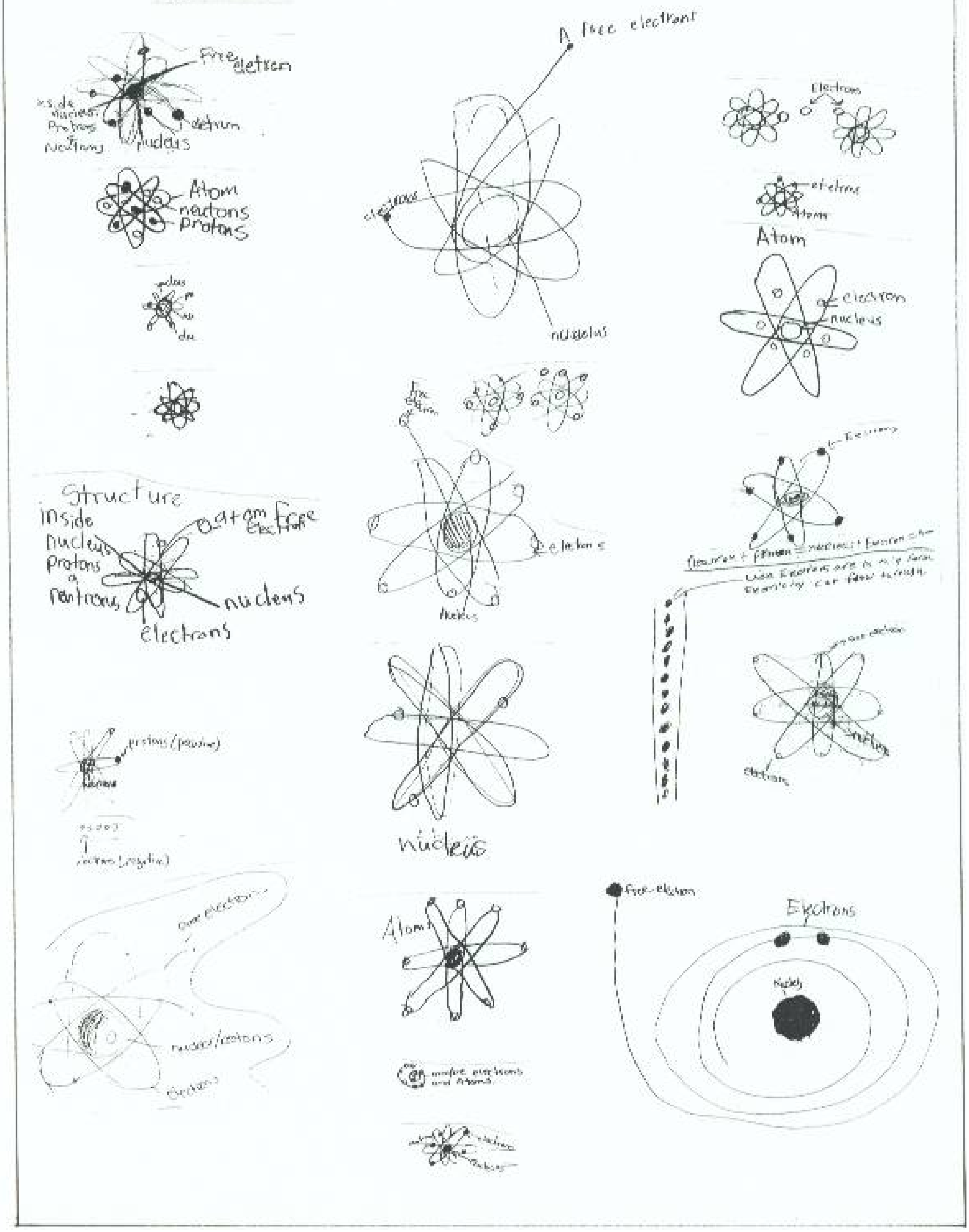
Students made pictures (from Canada)

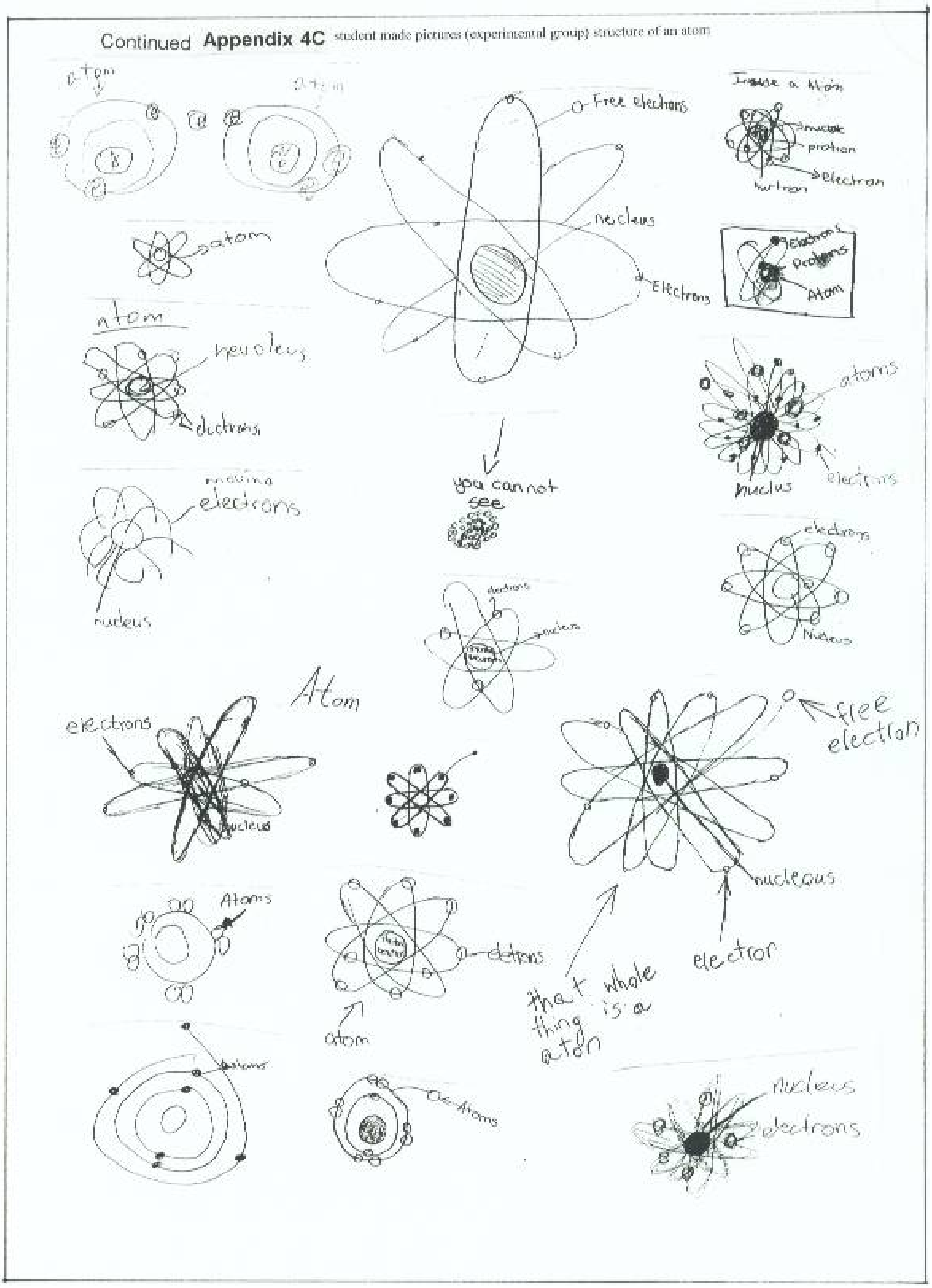
Appendix 4A Student made pictures (experimental group) simple circuits



Appendix 4B Student made pictures (experimental group) example of static electricity

Appendix 4C student made pictures (experimental group) structure of an atom

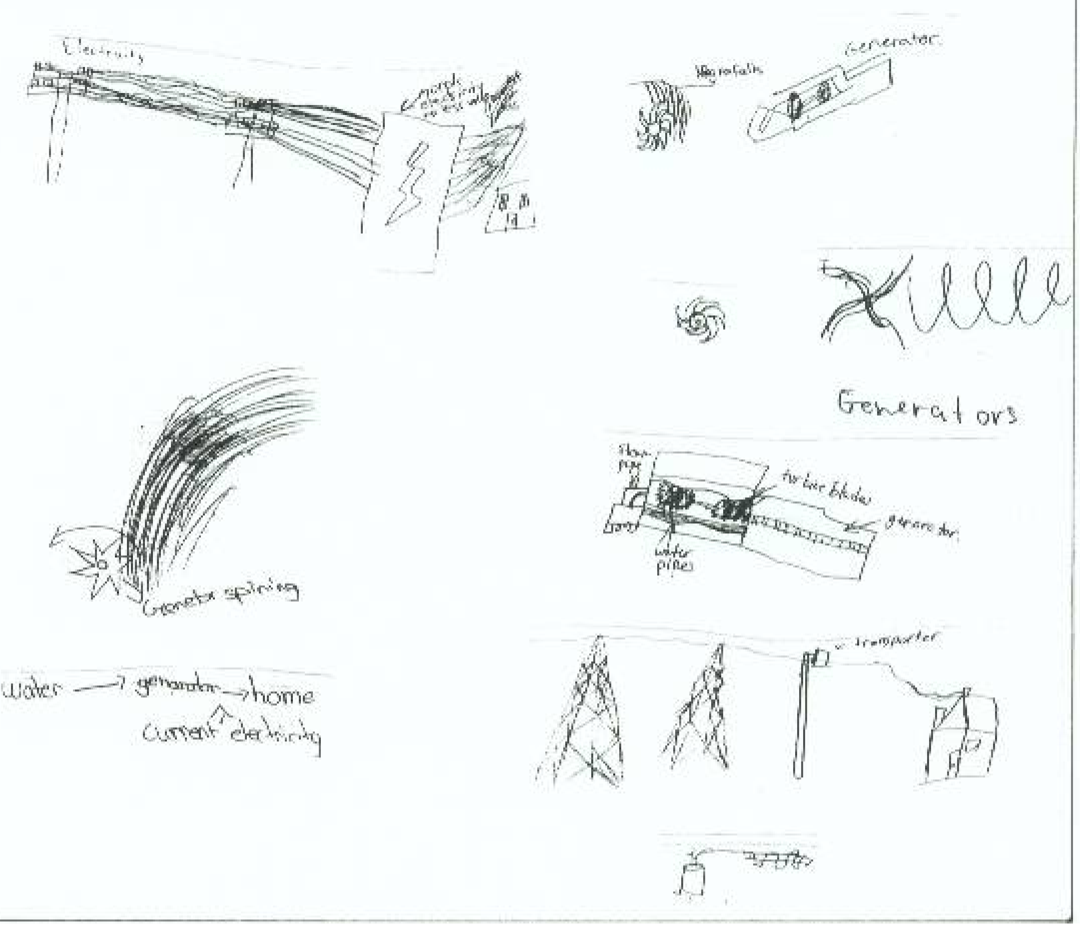



Continued Appendix 4C student made pictures (experimental group) structure of an atom
atom
atom
Free electrons
Inside a Atom
nucleus
proton
electron
nutron
nucleus
Electrons
atom
Electrons
Protons
Atom
atom
neuoleus
electrons
atoms
nuclus
electrons
moving electrons
nucleus
you can not see
electrons
nucleus
electrons
Nucleus
Atom
electrons
nucleus
free electron
Atoms
electrons
nucleous
atom
electron
that whole thing is a aton
atoms
atoms
nucleus
electrons

Appendix 4D Student made pictures (experimental group) AC and DC

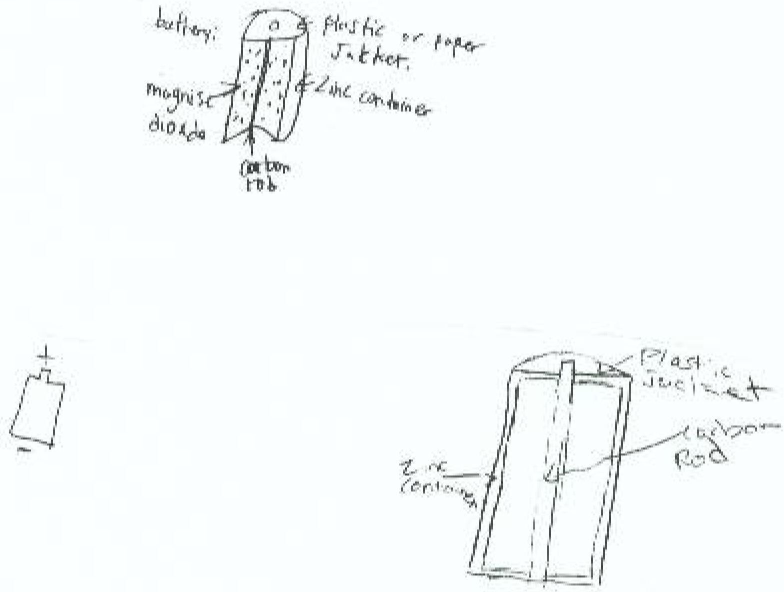
Differentiate between AC and DC

Appendix 4E Student made pictures (experimental group) generation of electricity

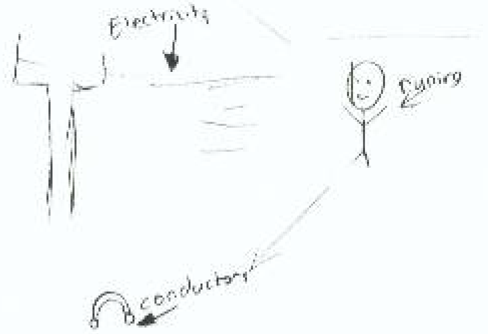


Appendix 4 F Student made pictures (experimental group) bulbs

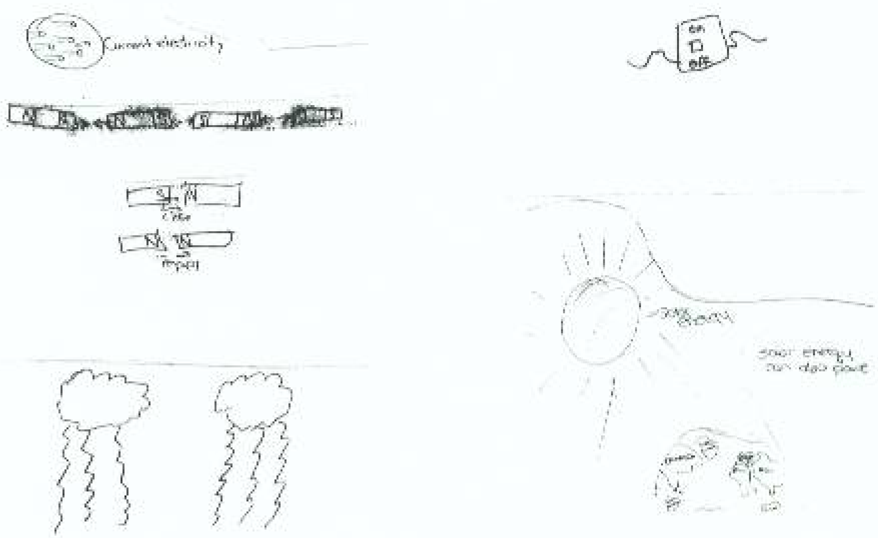
Appendix 4 G Student made pictures (experimental group) battery



Appendix 4 H Student made pictures (experimental group) conductors and insulators



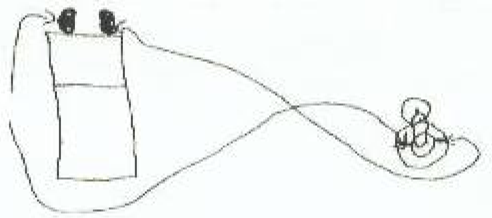
Appendix 4 I (below) Student made pictures (experimental group) others



Appendix 4 J Student made pictures (control group) simple circuits

Control Group

Functions of a simple circuit (battery, bulb, wires)



Appendix 5A

Sentence analysis of the textbook (PT)

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
1	In the previous class, we have learnt about the electric circuit.	WR
2	When the switch of an electric circuit is turned on, the bulb in the circuit is lighted.	R
3	This shows that the current has started to flow in the circuit.	R
4	We also know that the current is the flow of electric charges.	WR
5	Infact, these flowing changes are the electrons.	WR
6	We know that nobody moves by itself.	WR
7	Energy is required to move it.	WR
8	The question arises, from where does energy come to maintain the flow of electrons in a circuit?	WR
9	The answer is that a dry cell or a battery provides this energy.	R
10	There is abundance of electrons at the negative terminal of the dry cell and much less electrons at the positive terminal.	R
11	This difference causes the flow of electrons.	R
12	The flow of electrons in an electric circuit is like water flowing through a pipe.	WR
13	The water flows from higher level to lower level through a pipe.	R
14	In the same way, the electrons flow from the end with more electrons to the end with less electrons through the wire.	R
15	When the circuit is turned on, the electrons start moving from the negative terminal of the battery or dry cell to the positive terminal through the circuit.	R
16	The energy of these moving electrons is called electric energy.	WR
17	When cells were first invented, scientists guessed wrongly that	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	something (current) was moving from positive to negative terminal of the cell.	
18	Later on, they came to know that electric current is really a flow of electrons from negative to positive terminal.	WR
19	However, we have kept to this convention.	WR
20	When drawing circuit diagrams, usually the direction of current is indicated by making arrows from negative terminal of the cell.	WR
21	This is called conventional current.	WR
22	We know that electric current can pass through "conductors" whereas it cannot pass through "insulators".	WR
23	As the current passes through metallic wires, So these wires are called conductors.	WR
24	Copper wires are usually used to connect components of a circuit i.e. battery, bulbs and switch etc.	WR
25	The filament that glows in a bulb is also a wire made of tungsten metal.	WR
26	We will call all such wires as conductors.	WR
27	Can current pass through different wires equally easily?	WR
28	Let us perform the following activity to understand it.	WR
29	Connect a battery, a bulb and a switch with the help of connecting wires to make a circuit as shown in Fig.15.2(a).	WR
30	The piece of wire connected between the switch and the bulb should be a 50cm long copper wire.	WR
31	Turn the switch on and observe the lighted bulb.	WR
32	Now turn off the switch, and replace the copper wire between switch and the bulb by a 50cm long nichrome wire.	WR
33	Again observe the light of the bulb.	WR
34	Is the intensity of the light same as in the previous case or it is less	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	than that?	
35	What inference do you conclude?	WR
36	The electric current does not pass equally easily through all conductors.	WR
37	Different amounts of current pass through different conductors.	WR
38	Let us try to find out the reason why it is so.	WR
39	This is our common observation that the connecting wires are slightly heated up when a current flows through them.	WR
40	Likewise, a bulb filament starts emitting energy in the form of light and heat as current flows through it.	WR
41	This shows that the electric energy of the moving charges is converted into heat and light when current passes through a conductor.	WR
42	Due to loss of energy, the electric charges slow down and the current decreases.	R
43	The greater the energy is lost, the lesser will be the flow of current.	WR
44	The opposition offered by a conductor to the flow of current is called its resistance.	WR
45	Every conductor has some resistance.	WR
46	Different conductors have different resistances.	WR
47	In other words we can say: Different metallic wires of the same length and thickness have different resistances.	WR
48	For example, aluminum wire has more resistance than that of copper wire.	WR
49	The resistance of nichrome wire is even greater than these two (Fig. 15.2b).	WR
50	Nichrome wire is made by mixing nickel and chromium.	WR
51	As the nichrome wires become very hot due to their high resistance,	R

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=without reason **R**= reason
	therefore, these are used as elements in heaters or toasters etc. to produce heat.	
52	Conductors with high resistance are called "resistors".	WR
53	Thus, the filaments (elements) of bulb, electric heater, toaster etc. are all resistors.	WR
54	The resistors used in an electric circuit are also known as its "branches". (diagram)	WR
55	We have observed that different metallic wires of the same length and thickness have different resistances.	WR
56	Let us now see whether the resistance of a wire changes with change in its length?	WR
57	Take a battery of three cells, a bulb of three volts and a switch.	WR
58	Stretch a piece of nichrome wire (heater element) over a metre rod with the help of adhesive tape.	WR
59	Join a connecting wire to one end of the nichrome wire at the zero point of the metre rod.	WR
60	Make a circuit as shown in Fig. 15.3.	WR
61	Join a crocodile clip to the free end of the wire connected to the bulb.	WR
62	The naked end of the connecting wire can also work if crocodile clip is not available.	WR
63	Press the naked end of the wire or clip at 20cm on the nichrome wire.	WR
64	Observe the lighted bulb.	WR
65	Repeat the observation at 40cm and then at 60cm on the nichrome wire.	WR
66	Does the intensity of light decrease or increase with increase in	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	length of nichrome wire?	
67	Does the resistance decrease or increase?	WR
68	We see that: the resistance of a conductor increases with increase in its length.	WR
69	In many experiments of electricity, we require resistors of some fixed values.	WR
70	A resistance box is usually used for this purpose.	WR
71	A typical resistance box is shown in Fig. 15.4.	WR
72	There are many resistors of fixed values installed inside the box and their values are marked over the box.	WR
73	Plug keys are removed to insert the required resistors in the circuit.	WR
74	The resistance introduced in the circuit is equal to the sum of the resistances indicated by the keys which have been removed.	WR
75	We have already learnt that when a battery, resistors (bulb etc.) and switch are connected through wires in such a way that the current starts flowing through the components, it is called an electric circuit.	WR
76	In Fig. 15.1, a circuit is shown with one bulb.	WR
77	Since it is difficult and time consuming to draw the pictures of all these components, it is convenient to use their symbols.	WR
78	The figure drawn with the help of symbols of the components is called a circuit diagram.	WR
79	Symbols of some components are shown below: (figure)	WR
80	The circuit diagram of fig.15.1 will be drawn as shown in Fig.15.5.	WR
81	Look at the figure again.	WR
82	There is only one bulb used in this circuit.	WR
83	If more than one bulb are to be connected in a circuit, two method are used to do so.	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
84	These are called as:1.Series Circuit 2.Parallel Circuit	WR
85	Take a battery of two cells, three similar bulbs and a switch.	WR
86	Connect all these components one after the other as shown in Fig. 15.6.	WR
87	Turn the switch on and make the following observations.	WR
88	Have all the bulbs been lighted?	WR
89	Is the intensity of light of all the bulbs the same?	WR
90	Place your finger at the negative terminal of the battery and move it along the path you think the current is flowing through upto the positive terminal.	WR
91	Can you find how many paths are there for the current to flow?	WR
92	Now take out any one bulb from the circuit.	WR
93	Do all the remaining bulbs keep on lighted?	WR
94	An electric circuit in which there is only one path of current to flow is called a series circuit.	WR
95	It is the characteristic of a series circuit that the same current passes through all its resistors or branches and it is equal to the total current of the circuit.	WR
96	The drawback of this circuit is that a break in any one branch causes the break in the whole circuit.	R
97	This is why a series circuit is not used for household wiring.	R
98	In this circuit, there are as many paths of current to flow as there are number of branches in it.	WR
99	It is the characteristic of a parallel circuit that the same current does not pass through all the branches.	WR
100	The current is divided while passing through the branches.	WR
101	In this way the total current of the circuit is equal to the sum of the currents passing through all the branches.	R

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
102	The advantage of such a circuit is that a break in any one branch does not break the whole circuit.	WR
103	An electric circuit in which there are more than one paths of current to flow is called a parallel circuit.	WR
104	Connect three bulbs in parallel and then join them with the battery and switch as shown in Fig. 15.7.	WR
105	Turn the switch on.	WR
106	Have all the bulbs been lighted?	WR
107	Is the intensity of light of all the bulbs the same as that of bulbs connected in series or it is less than that?	WR
108	Now place your finger at the negative terminal of the battery and try to trace all the possible paths through which you think the current might be flowing to reach the positive terminal.	WR
109	How many paths are there in this case?	WR
110	Now remove any one of the bulbs.	WR
111	Do the other bulbs remain lighted?	WR
112	You have studied both the methods of making electric circuit.	WR
113	In your opinion which one is more suitable for the household wiring and why?	WR
114	We know that the household electric appliances such as bulbs, tube lights, fans, television, refrigerators etc. are not used all at a time.	WR
115	Therefore such circuit is required in which there is a separate path for the flow of current for each appliance.	R
116	This will facilitate us to switch on one or more appliances while keeping the others off.	R
117	That is why, the parallel circuit method is used for the household wiring.	R
118	You might have seen that there is a separate switch for each	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	appliance in the home.	
119	Only that device works which is turned on, whereas all the other remain off.	WR
120	(Summary)	
121	Current is the flow of electric charges.	WR
122	The energy of the moving charges is known as electric energy.	WR
123	Electrons move from negative terminal to positive terminal of the battery in an electric circuit.	WR
124	The opposition offered by a conductor to the flow of current is called its resistance.	WR
125	A conductor having high resistance is called a resistor.	WR
126	Different conductors have different resistances.	WR
127	Different metallic wires of the same length and thickness have different resistances.	WR
128	The resistance of a wire increases with increase in its length.	R
129	There are two types of electric circuits. (a) Series circuit (b) Parallel circuit	WR
130	An electric circuit in which there are more than one paths for current to flow is called a parallel circuit.	WR
131	The break in any one of its branches does not break the whole circuit.	WR
132	The parallel circuit method is used for household wiring.	WR
133	(Glossary)	
134	Current: Flow of electric charges.	WR
135	Electric energy: The energy of moving charges.	WR
136	Conductor: Through which the current can pass easily.	WR
137	Electric resistance: The opposition to the flow of current.	WR
138	Resistor: A conductor with high resistance.	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=without reason **R**= reason
139	Electric Circuit: the connection of resistors, switch and battery.	WR
140	Series Circuit: A circuit having only one path for current flow.	WR
141	Parallel Circuit: A circuit having more than one paths for current flow.	WR
142	Branches: The resistors connected in a circuit.	WR
143	(Chapter 16)	
144	We know that the Earth is huge magnet.	WR
145	That is why the compass needle always rests almost along north-south direction.	R
146	In the previous class, we studied about permanent magnet and its properties.	WR
147	Now we will study whether magnetic effects are produced in a coil when an electric current is flowing through it?	WR
148	Take a battery of two cells.	WR
149	Wind some cotton covered copper wire lightly over an iron nail, thus forming a coil.	WR
150	Suspend the coil by means of a thread tied to its centre.	WR
151	Now connect ends of the coil to the terminals of the battery through a switch as shown in Fig. 16.1.	WR
152	Keeping the switch off, observe carefully whether the coil rests north-south wise.	WR
153	Now put some magnetic substances like paper pins or iron filings on a piece of paper and bring them close to one end of the nail.	WR
154	Do they stick to the nail?	WR
155	Turn the switch on and again observe whether the coil rests north-south wise?	WR
156	Bring paper pins close to the end of the nail.	WR
157	Do they stick to the nail this time?	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) ‘the image is upside down because light travels in straight lines and the rays cross at the pinhole.’ (b) ‘We have a translucent screen opposite the pinhole so that you can see the image’ (c) ‘I made the pinhole camera because I want to figure out how it works.’ (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
158	Does the nail behave like a magnet?	WR
159	Turn the switch off, and again observe whether the nail attracts the paper pins towards it or not?	WR
160	What inference do you deduce from it?	WR
161	An iron rod or nail becomes a magnet when electric current passes through a coil around it.	WR
162	It is called an electromagnet.	WR
163	The magnetic properties of an electromagnet are temporary.	WR
164	Let us now observe whether the strength of an electromagnet can be enhanced or reduced?	WR
165	Take an iron paper clip.	WR
166	Straighten its one end.	WR
167	Bring it close to one pole of the electromagnet which was made in activity 16.1.	WR
168	Clip will stick to it.	WR
169	Now suspend another clip over the straight end of the first clip.	WR
170	Do they fall down?	WR
171	If not, suspend more clips one by one until they fall down.	WR
172	Count the number of clips held by the electromagnet.	WR
173	Now double the number of cells and repeat the above activity.	WR
174	Count their number.	WR
175	Reduce the number of cells to two again and double the number of turns of the coil.	WR
176	Repeat the above activity.	WR
177	How many clips are held by the electromagnet this time?	WR
178	What can we infer from it?	WR
179	More number of clips held means the strength of the electromagnet has increased.	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
180	The strength of the electromagnet increases with the increase in electric current or increase in the number of turns of the coil.	WR
181	Danish scientist Hans Oersted was the first to explore electromagnetic effect.	WR
182	This discovery brought a revolution in the world of science and engineering.	WR
183	Special cranes are designed to lift heavy objects in the iron and steel industry.	WR
184	They have electromagnets instead of hooks at the end of steel cables.	WR
185	The electromagnet is brought closer to lift the object, which is to be moved.	WR
186	Then it is carried to the destination and released there by switching off the current flow (Fig. 16.3 a&b).	WR
187	It has been observed through above mentioned activities that an electromagnet attracts iron objects.	WR
188	This property of electromagnets is the base of working principle of the following devices.	WR
189	Different parts of an electric bell are shown in Fig. 16.4.	WR
190	When push button (switch) is pressed, the electric circuit is completed and current starts flowing through the coil, which becomes an electromagnet.	R
191	It attracts the elastic iron strip constantly.	WR
192	The hammer attached to the strip strikes the gong of the bell and produces sound.	WR
193	In doing so the strip is detached from the screw at point C.	WR
194	The electric circuit breaks and the current stops.	WR
195	The coil no longer remains electromagnet.	WR
196	Therefore, the strip moves back and comes in contact with the	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
	screw.	
197	This completes the circuit again and the action is repeated.	WR
198	The hammer continues to strike the gong as long as the push button is kept pressed.	WR
199	A surgeon picks out iron bits entered accidentally into the eye with the help of a sensitive electromagnet.	WR
200	The rotation of an electric fan is also due to an electromagnet.	WR
201	A tiny electromagnet converts sound waves in the microphone into electric current, which is reconverted into sound on reaching the receiver on the other end.	WR
202	Thus electromagnet is the basic component of the telephone.	WR
203	The recording and play functions in a tape-recorder and VCR are performed by tiny electromagnets.	WR
204	The bullet trains in Japan and France run over electromagnetic track instead of ordinary rails.	WR
205	(Summary)	
206	Magnetic effects are produced in a coil through which an electric current is flowing.	WR
207	An iron rod or nail becomes a magnet when electric current passes through a coil around it. It is called an electromagnet.	WR
208	The magnetic properties vanish when the current stops flowing through the coil.	WR
209	The strength of the electromagnet increases when the number of turns of the coil or the number of cells of the battery are increased.	WR
210	The properties of an electromagnet are the same as those of a permanent magnet.	WR
211	The magnetic properties of an electromagnet are temporary.	WR
212	Electromagnets are used in the devices like crane and electric bell.	WR

No.	**Sentences from the textbook** Note: A sentence that provides no reason is classified as **WR** (without reason) **R**= Provides some type of reason, for e.g. (a) 'the image is upside down because light travels in straight lines and the rays cross at the pinhole.' (b) 'We have a translucent screen opposite the pinhole so that you can see the image' (c) 'I made the pinhole camera because I want to figure out how it works.' (based on Newton et al. 2002: 228)	**WR**=with-out reason **R**= reason
213	(Glossary)	
214	Earth's magnetism: The behaviour of Earth as a huge magnet.	WR
215	Magnetic material: Such materials which are attracted by a magnet.	WR
216	Electromagnet: A magnet working due to flow of current through a coil.	WR
217	Temporary magnet: An electromagnet which shows magnetic effect only during the flow of current.	WR

Appendix 5B

Paragraph analysis (PT)

The columns with 1,2,3,4 indicate the following:

(1) discusses daily life use of electricity, electricity resources; (2) asks readers to 'think about', ' imagine', 'don't you think', asks questions, asks to identify, asks to compare; (3) explains something using reason(s); (4) Includes numeric values (2 km, 1000 kWh, 1888 AD)

No.	**Paragraphs**	1	2	3	4
1	In the previous class, we have learnt about the electric circuit. When the switch of an electric circuit is turned on, the bulb in the circuit is lighted. This shows that the current has started to flow in the circuit. We also know that the current is the flow of electric charges. Infact, these flowing changes are the electrons.			x	
2	We know that nobody moves by itself. Energy is required to move it. The question arises, from where does energy come to maintain the flow of electrons in a circuit? The answer is that a dry cell or a battery provides this energy. There is abundance of electrons at the negative terminal of the dry cell and much less electrons at the positive terminal. This difference causes the flow of electrons.		x	x	
3	The flow of electrons in an electric circuit is like water flowing through a pipe. The water flows from higher level to lower level through a pipe. The water flows from higher level to lower level through a pipe. In the same way, the electrons flow from the end with more electrons to the end with less electrons through the wire. When the circuit is turned on, the electrons start moving from the negative terminal of the battery or dry cell to the positive terminal through the circuit. The energy of these moving electrons is called electric energy.			x	

No.	Paragraphs	1	2	3	4
4	When cells were first invented, scientists guessed wrongly that something (current) was moving from positive to negative terminal of the cell. Later on, they came to know that electric current is really a flow of electrons from negative to positive terminal. However, we have kept to this convention. When drawing circuit diagrams, usually the direction of current is indicated by making arrows from negative terminal of the cell. This is called conventional current.	x			
5	We know that electric current can pass through "conductors" whereas it cannot pass through "insulators". As the current passes through metallic wires, So these wires are called conductors. Copper wires are usually used to connect components of a circuit i.e. battery, bulbs and switch etc. The filament that glows in a bulb is also a wire made of tungsten metal. We will call all such wires as conductors. Can current pass through different wires equally easily? Let us perform the following activity to understand it.	x	x		
6	Connect a battery, a bulb and a switch with the help of connecting wires to make a circuit as shown in Fig.15.2(a). The piece of wire connected between the switch and the bulb should be a 50cm long copper wire. Turn the switch on and observe the lighted bulb. Now turn off the switch, and replace the copper wire between switch and the bulb by a 50cm long nichrome wire. Again observe the light of the bulb. Is the intensity of the light same as in the previous case or it is less than that? What inference do you conclude?		x		
7	Let us try to find out the reason why it is so. This is our common observation that the connecting wires are slightly heated up when a current flows through them. Likewise, a bulb filament starts emitting energy in the form of light and heat as current flows through it. This shows that the electric energy of the moving charges is converted into heat and light when current passes through a conductor. Due to loss of energy, the electric charges slow down and the current decreases. The greater the energy is lost, the lesser will be the flow of current.			x	

No.	**Paragraphs**	1	2	3	4
8	Conductors with high resistance are called “resistors”. Thus, the filaments (elements) of bulb, electric heater, toaster etc. are all resistors. The resistors used in an electric circuit are also known as its “branches”.		x		
9	We have observed that different metallic wires of the same length and thickness have different resistances. Let us now see whether the resistance of a wire changes with change in its length?		x		
10	Take a battery of three cells, a bulb of three volts and a switch. Stretch a piece of nichrome wire (heater element) over a metre rod with the help of adhesive tape. Join a connecting wire to one end of the nichrome wire at the zero point of the metre rod. Make a circuit as shown in Fig. 15.3. Join a crocodile clip to the free end of the wire connected to the bulb. The naked end of the connecting wire can also work if crocodile clip is not available. Press the naked end of the wire or clip at 20cm on the nichrome wire. Observe the lighted bulb. Repeat the observation at 40cm and then at 60cm on the nichrome wire. Does the intensity of light decrease or increase with increase in length of nichrome wire? Does the resistance decrease or increase?		x		X
11	In many experiments of electricity, we require resistors of some fixed values. A resistance box is usually used for this purpose. A typical resistance box is shown in Fig. 15.4. There are many resistors of fixed values installed inside the box and their values are marked over the box. Plug keys are removed to insert the required resistors in the circuit. The resistance introduced in the circuit is equal to the sum of the resistances indicated by the keys which have been removed.	x			
12	We have already learnt that when a battery, resistors (bulb etc.) and switch are connected through wires in such a way that the current starts flowing through the components, it is called an electric circuit.	x			

No.	**Paragraphs**	1	2	3	4
13	In Fig. 15.1, a circuit is shown with one bulb. Since it is difficult and time consuming to draw the pictures of all these components, it is convenient to use their symbols. The figure drawn with the help of symbols of the components is called a circuit diagram. Symbols of some components are shown below:	x			
14	The circuit diagram of fig.15.1 will be drawn as shown in Fig.15.5. Look at the figure again. There is only one bulb used in this circuit. If more than one bulb are to be connected in a circuit, two method are used to do so. These are called as: 1.Series Circuit 2.Parallel Circuit	x			
15	Take a battery of two cells, three similar bulbs and a switch. Connect all these components one after the other as shown in Fig. 15.6. Turn the switch on and make the following observations. Have all the bulbs been lighted? Is the intensity of light of all the bulbs the same? Place your finger at the negative terminal of the battery and move it along the path you think the current is flowing through upto the positive terminal. Can you find how many paths are there for the current to flow? Now take out any one bulb from the circuit. Do all the remaining bulbs keep on lighted?	x	x		
16	It is the characteristic of a series circuit that the same current passes through all its resistors or branches and it is equal to the total current of the circuit. The drawback of this circuit is that a break in any one branch causes the break in the whole circuit. This is why a series circuit is not used for household wiring.			x	
17	In this circuit, there are as many paths of current to flow as there are number of branches in it. It is the characteristic of a parallel circuit that the same current does not pass through all the branches. The current is divided while passing through the branches. In this way the total current of the circuit is equal to the sum of the currents passing through all the branches. The advantage of such a circuit is that a break in any one branch does not break the whole circuit.			x	

No.	**Paragraphs**	1	2	3	4
18	Connect three bulbs in parallel and then join them with the battery and switch as shown in Fig. 15.7. Turn the switch on. Have all the bulbs been lighted? Is the intensity of light of all the bulbs the same as that of bulbs connected in series or it is less than that? Now place your finger at the negative terminal of the battery and try to trace all the possible paths through which you think the current might be flowing to reach the positive terminal. How many paths are there in this case? Now remove any one of the bulbs. Do the other bulbs remain lighted?		x		
19	You have studied both the methods of making electric circuit. In your opinion which one is more suitable for the household wiring and why?		x		
20	We know that the household electric appliances such as bulbs, tube lights, fans, television, refrigerators etc. are not used all at a time. Therefore such circuit is required in which there is a separate path for the flow of current for each appliance. This will facilitate us to switch on one or more appliances while keeping the others off. That is why, the parallel circuit method is used for the household wiring. You might have seen that there is a separate switch for each appliance in the home. Only that device works which is turned on, whereas all the other remain off.			x	
21	We know that the Earth is huge magnet. That is why the compass needle always rests almost along north-south direction. In the previous class, we studied about permanent magnet and its properties. Now we will study whether magnetic effects are produced in a coil when an electric current is flowing through it?			x	
22	Take a battery of two cells. Wind some cotton covered copper wire lightly over an iron nail, thus forming a coil. Suspend the coil by means of a thread tied to its centre. Now connect ends of the coil to the terminals of the battery through a switch as shown in Fig. 16.1.	x			

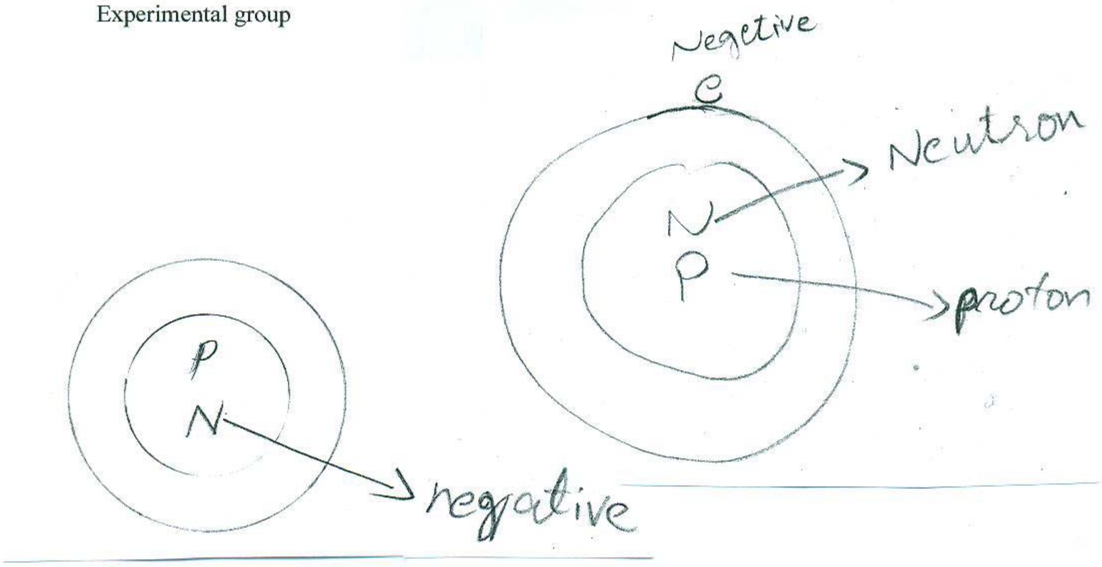
No.	**Paragraphs**	1	2	3	4
23	Keeping the switch off, observe carefully whether the coil rests north-south wise. Now put some magnetic substances like paper pins or iron filings on a piece of paper and bring them close to one end of the nail. Do they stick to the nail? Turn the switch on and again observe whether the coil rests north-south wise? Bring paper pins close to the end of the nail. Do they stick to the nail this time? Does the nail behave like a magnet? Turn the switch off, and again observe whether the nail attracts the paper pins towards it or not? What inference do you deduce from it?		x		
24	Take an iron paper clip. Straighten its one end. Bring it close to one pole of the electromagnet which was made in activity 16.1. Clip will stick to it. Now suspend another clip over the straight end of the first clip. Do they fall down? If not, suspend more clips one by one until they fall down. Count the number of clips held by the electromagnet. Now double the number of cells and repeat the above activity. Can the electromagnet hold more number of clips now? Count their number. Reduce the number of cells to two again and double the number of turns of the coil. Repeat the above activity. How many clips are held by the electromagnet this time? What can we infer from it? More number of clips held means the strength of the electromagnet has increased.		x		
25	Special cranes are designed to lift heavy objects in the iron and steel industry. They have electromagnets instead of hooks at the end of steel cables. The electromagnet is brought closer to lift the object, which is to be moved. Then it is carried to the destination and released there by switching off the current flow (Fig. 16.3 a&b).	x			
26	It has been observed through above mentioned activities that an electromagnet attracts iron objects. This property of electromagnets is the base of working principle of the following devices.	x			

No.	**Paragraphs**	1	2	3	4
27	Different parts of an electric bell are shown in Fig. 16.4. When push button (switch) is pressed, the electric circuit is completed and current starts flowing through the coil, which becomes an electromagnet. It attracts the elastic iron strip constantly. The hammer attached to the strip strikes the gong of the bell and produces sound. In doing so the strip is detached from the screw at point C. The electric circuit breaks and the current stops. The coil no longer remains electromagnet. Therefore, the strip moves back and comes in contact with the screw. This completes the circuit again and the action is repeated. The hammer continues to strike the gong as long as the push button is kept pressed.	x		x	

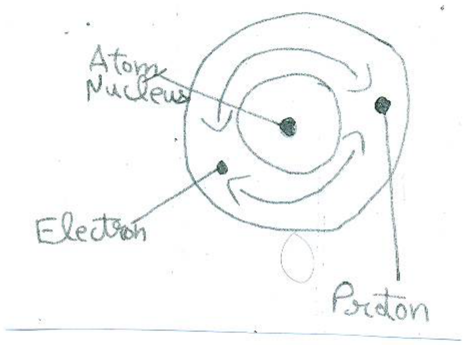
Appendix 6

Students made pictures (from Pakistan)

Experimental group



Control group



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