Revista Brasileira de Ensino de Física, v. 35, n. 1, 1501 (2013)
www.sbfisica.org.br

Desenvolvimento em Ensino de Física

An analysis of grade six textbook on electricity through content analysis and student writing responses

(Análise de um livro-texto de eletricidade, do sexto grau, através de análise de conteúdo e das respostas escritas dos alunos)

Altaf Qadeer[1]

Site-Coordinator for teacher training programs, York University, Toronto, Canada
Recebido em 27/2/2012; Aceito em 14/6/2012; Publicado em 18/2/2013

Science textbooks have to provide scientific reasons for various themes, but in some cases this is not properly emphasized. Using a document analysis method for classifying sentences and paragraphs, a sixth grade textbook on electricity that is used in Toronto is analyzed. Student writing responses are also analyzed to explore students' reflections to indicate their ways of explaining the concepts of electricity. The document analysis indicates lack of sentences to provide reasons. Although some everyday aspects of electricity are found in the textbook, the links between electricity and electrons are not clearly demonstrated in the document analysis and student responses. This finding can help to incorporate learning reasons in scientific processes through teaching and textbook designing.
Keywords: explanatory sentences, explanatory understanding, document analysis, textbook analysis, lexical conceptual profile, paragraph analysis, science concepts, science curriculum.

Livros-texto de ciência têm que fornecer as razões científicas para todos os temas, mas em alguns casos isso não é devidamente enfatizado. Usando um método de análise de documentos para a classificação de frases e parágrafos, um livro da sexta série sobre eletricidade, utilizado em Toronto, é analisado. Respostas escritas de estudantes também são analisadas para explorar as suas reações e indicar as suas formas de explicar os conceitos de eletricidade. A análise do documento revela falta de frases para fornecer as razões dos fenômenos físicos. Embora alguns aspectos cotidianos da eletricidade sejam encontrados nesse livro, as conexões entre eletricidade e elétrons não são claramente evidentes na análise de documentos e nas respostas dos alunos. Esta conclusão pode ajudar a incorporar as causas dos processos científicos no ensino e na preparação de livros didáticos.
Palavras-chave: sentenças explicativas, compreensão explicativa, análise de documentos, análise de livros-texto, análise de parágrafos, conceitos científicos, currículo e ciências.

1. Introduction

Science education requires understanding reasons for various processes and phenomenon. This means, not just knowing the facts and learning about the everyday use of electrical appliances but what is electricity and how things work using electricity is an important goal in science education. Science learning has a close link with learning concepts, which are considered of high importance to gain insight in science [1]. Science concepts are commonly very abstract and some ideas overlap in a variety of themes, as a result it becomes essential to provide explanatory understanding to facilitate concept formation [1].

Keil and Wilson have explained the notion of reason and everyday observation to distinguish between the two processes. According to Keil and Wilson [2, p. 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.

[1] E-mail: altafqadeer@yahoo.com.

In order to bring science understanding closer to the children level, the use of explanatory sentences is an important tool [3]. One of the reasons for lack of communication of science related ideas to non-scientist community is due to the use of complex language with sophisticated vocabulary [4]. Gould has questioned as to why scientific text has to be so unreadable [4]. If the language is simplified in the science books/articles, this may facilitate one dimension of communicating the concepts. While comparing the nature of explanation in science, Keil and Wilson [2, p. 281] have found many commonalities between the explanation of scientists and non-scientists. In order to enhance this process, the need to link theory, research and practice is growing (Fig. 1).

Explanatory understanding is considered an important aspect in learning science, however, in many cases it is not necessarily a major focus on our concept attaining processes [3,4]. In general, understanding has three important functions: connecting information pieces, connecting unknown with known information, and constructing knowledge with integration [5]. 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.

The extensive use of explanatory sentences gives some indication of showing concern for explanatory understanding in a textbook [2,3]. 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 and others have established a schedule to find the presence of various types of clauses used in the textbook [3].

Textbooks have been studied from various dimensions in the previous studies. In the context of explanatory understanding, Newton and others [3] 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 and others [3] 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" [3, p. 230]. Those authors have [3] discovered 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). Fraenkel and Wallen [6] 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.

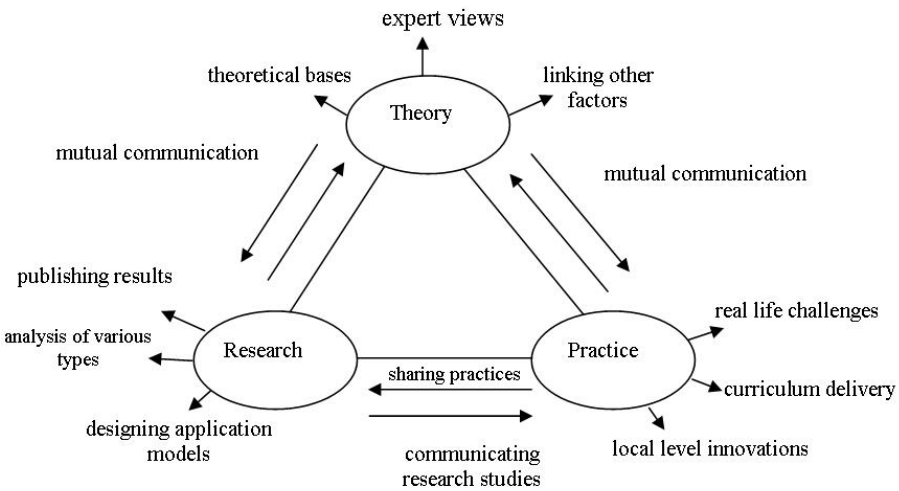

Figure 1 - Communication between the three domains of science in science education.

Textbook analysis provides critical data for various parameters of learning. Educators use textbooks for preparing lessons and delivering the curriculum. 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 science textbooks (this can be confirmed by reliable internet search engines such as ERIC). Since there are very few studies conducted on textbook analysis of Canada, therefore, conducting a study on this theme becomes a need to fill in the research gap. 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. A textbook study can provide some insight in investigating the challenges of the learning environment.

The purpose of this study highlights the indicators of explanatory aspects in the science textbook (*Electricity - Science & Technology* published by Addison and Wesley 1999), compares the feedback of students on the use of this textbook, and relates the discussions on data. This is also a distinction of the current study. Overall, many studies conducted on the textbooks normally apply one type of analysis method. The current study is based on the responses of students and document analysis of the textbook. Another aspect of the originality of this study is analyzing the textbook contents *Electricity-Science & Technology* published by Addison and Wesley 1999 for comparing sentences, paragraphs, and key-words. There is no study conducted on this textbook to explore those factors in a single research. There is no other study conducted in the past which incorporates these content analysis frames together for any textbook. This discussion shows the significance, justification and originality of this current study.

2. Methodology

Reasoning plays an important role to promote explanatory understanding in science. Science textbooks have to provide reasons of various science concepts [1]. Concepts related to electricity may include where we use electricity in our daily lives or how we can be responsible to use electricity for environmental purposes. One of the more scientific reasoning related ideas revolves around what is electricity, what are atoms, protons and electrons? And obviously, there could be many details which can be provided according to the learning level of the students. In order to explore the reasoning given in the textbooks; one way is to explore the scientific reasoning reflected in the sentences of the textbooks. This study has collected data to show such aspects of the textbook analyzed. As the ERIC data confirms that no such study was conducted in the past which comprises document analysis on this textbook along with students' written responses in their usual classroom learning. Within the significant parameters of this study, it provides pathways which can be extended for further studies.

Data analysis for such tasks requires comparing various aspects of information given and the way students have attained the concepts. Unidimensional tests can not provide highly useful information, therefore multidimensional data is needed to compare certain information related to learning factors [7]. Although there is no specific research method for textbook analysis, a combination of methods has been used by various researchers [8]. This study has used document analysis (sentence analysis, paragraph comparisons, and some qualitative feedback) and student responses as they wrote about their understanding of various concepts from this textbook in a usual ongoing learning process. An advantage of document analysis is that it non-obtrusive [6]. One of the basic focuses of document analysis requires researcher to define categories and formulate certain classification in such a way that if other researchers compare the same characteristic of the document, they reach the same conclusions [6]. Although textbook study does not have a specific method of analysis, however, the research parameters, category classification and content comparison requires a consistent formulation for the study.

Berelson [9, p. 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 [10, 11]. The multipurpose nature of content analysis is also discussed by some scholars. Holsti [11, p. 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 [6, p. 548] document or content analysis is "the process of inductively establishing a categorical system for organizing open-ended information." Weber [12, p. 9] discussed content analysis procedure as "a research method that uses a set of procedures to make valid inferences from text." Another advantage of content analysis is that the researcher can observe various content aspects without being observed [6]. 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 [6]. The above discussion shows a variety of ways in which researchers have identified the content analysis procedures. Lee [10, p. 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."

This rationale provides supporting grounds for conducting textbook analysis to find the frequency of certain indicators 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 the framework of this study.

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" [13]. 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 [13, p. 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. What will constitute that balance among the four factors being analyzed for grade six level students? Some extended versions of content analysis are also used according to the nature of text [6].

In the current study, one type of content analysis is applied on the sentences of the textbook (sentences which provide a reason and the sentences which provide no reason). 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. 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 some categories for the 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 ideas communicated. The process of categorization of sentences and paragraphs is explained in the examples given in Table 2 and 5.

The current study applies a combination of selected strategies according to the scope of this study (Fig. 2). 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 60 students' responses and comparing the learning of these students using a multiple choice test and other written work. The rationale is to explore data from various dimensions. The learning process involved a multiple choice test as well as a writing task. This process reduces the chances of picking a correct answer just by a chance in the case of a multiple choice test. The results of this study can only be seen in the context of this particular study for the given text and the learners.

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 sentence classification of textbook shows precise comparison of each sentence and shows clear need for improvements. However, the comparison of all patterns of student comprehension patterns goes beyond the scope of this study.

The study is concerned with two basic questions.

(1) A science textbook (Electricity, grade six) shows lack of concern for explanatory understanding (based on the count of keywords, classification of sentences and other comparisons.)

(2) Students (grade six) show lack of use of keywords (25 keywords, lexical-conceptual profile) in their writing related to electrons and atoms.

2.1. Sample

The data collected for the textbook analysis of "Electricity" [14] is comprised of the following frameworks: picture count, sentence analysis of the textbook, paragraph analysis, lexical-conceptual profile (textbook), common multiple choice test, lexical-conceptual profile (students' writing), and student made pictures. The comparison of the data with interrelated relationships to other frameworks is given below. The rational for selecting this textbook for study includes many aspects. At the time of the study this textbook was referred on the website of the Ministry of Education, Ontario and therefore, it was in frequent use in the relevant schools. Grade six is the last grade of junior level in Ontario; therefore it was of scholarly interest to see how well students understand about the concept of electricity. The Curriculum of Ontario (in this case referred to 1998 curriculum) provides certain expectations for each strand of science. The topic of electricity is although very commonly discussed; how well students understand remains a topic for research studies, comparison and constant improvements. Students written work samples were used to explore the responses. Students were from various cultural backgrounds. A typical class is commonly comprised of a cross section of students with various learning levels and a balance of male and female students. The total pupils were sixty, out of them 29 were male and 31 were female.

3. Results

3.1. Picture count in the textbook

According to Alesandrini [15] 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 [15] 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.

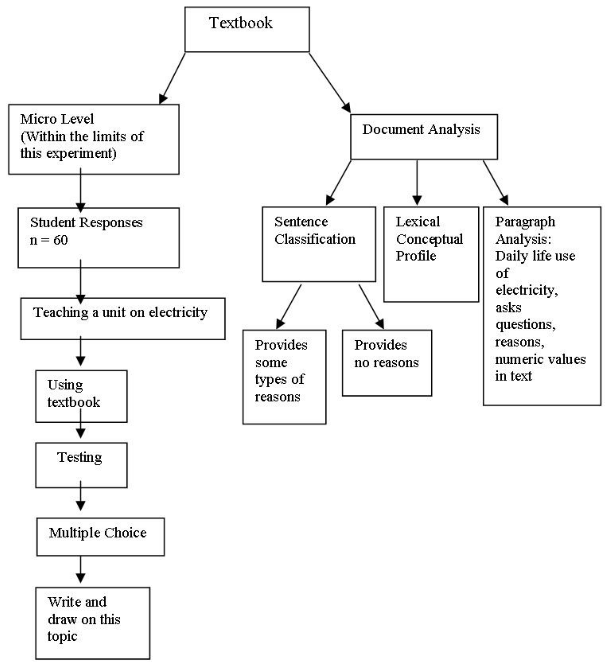

Figure 2 - Textbook analysis.

For the current analysis (Table 1), 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. The numbers of those pictures are significantly low as compared to the camera/computer group (including handmade pictures).

Table 1 - Picture Count in the textbook.

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

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.

3.2. Sentence classification of the textbook

The following Table 2 will show the sentences of the 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. Table 3 shows examples of sentence classifications.

Table 2 - Example of sentence classification of the textbook.

Sentences from 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 (reason) (based on Newton *et al.* 2002: 228)	
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 above analysis (Table 3) 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 [16] 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. In view of this standpoint, there is no simple relationship between the "reason-based" sentences and explanatory understanding [3], 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).

Table 3 - 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%

3.3. Lexical-conceptual profile

By searching some common definitions of the word 'electricity' and the focus of this research, 25 words were selected. 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 (Table 4). 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.

Table 4 - Lexical conceptual profile from the textbook (From the textbook), 10,350 total words.

Keywords	Word count	Absolute frequency	Relative frequency (out of 546 words used)
1.Electricity, electric, electrical	224	2.1643%	41.0256%
2. Form	1	0.0097%	0.1832%
3. Energy	72	0.6957%	13.1868%
4. Flow/flowing	3	0.0290%	0.5495%
5. Conductor/conduct	7	0.0676%	1.2821%
6. Movement	1	0.0097%	0.1832%
7. Electron(s)	0	0.0000%	0.0000%
8. Atom(s)	0	0.0000%	0.0000%
9. Matter	7	0.0676%	1.2821%
10. Radiation	0	0.0000%	0.0000%
11. Electromagnetic	0	0.0000%	0.0000%
12. Power	9	0.0870%	1.6484%
13. Physical	0	0.0000%	0.0000%
14. Protons	0	0.0000%	0.0000%
15. Attraction	0	0.0000%	0.0000%
16. Particles	0	0.0000%	0.0000%
17. Charge(s)	0	0.0000%	0.0000%
18. Repulsion	0	0.0000%	0.0000%
19. Light	73	0.7053%	13.3700%
20. Heat/heating	13	0.1256%	2.3810%
21. Work	11	0.1063%	2.0147%
22. Machine	1	0.0097%	0.1832%
23. Battery/Batteries	53	0.5121%	9.7070%
24. Current	3	0.0290%	0.5495%
25. Wire(s)	68	0.6570%	12.4542%

Table 5 - 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		

The lexical conceptual profile of the textbook (Table 4) indicates that some key-words, such as atom(s), electrons, protons, have zero frequency. An example of paragraph analysis is shown in Table 5. The paragraph analysis indicates only 8.43% of the paragraphs included some reasons (Table 6). This is also observed in the sentence analysis (Table 3). The number of paragraphs related to daily life use of electricity has a percentage of 44.57%. A large portion is devoted to this category of paragraphs. This indicates need to increase contents in the textbook which provide reasons for certain scientific processes. There were some paragraphs which can be considered paragraph overlap categories which are indicated in Table 7. The category 3, which includes reasons, has a very small percentage of overlap with other paragraphs.

Table 6 - Paragraph analysis (83 paragraphs in total).

No	Content category	Count	Percentage
1	1	37	44.57 %
2	2	33	39.75%
3	3	7	8.43%
4	4	19	22.89%

Table 7 - Paragraph overlap of categories.

No	Overlap	Count	Percentage
1	1,2	6	7.2%
2	2,3	1	1.2%
3	2,4	3	3.6%
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%

Common multiple choice test

A common multiple choice test was given to the students, (n = 60, male = 29, female = 31) to show what they understand about the term electricity. A learning unit was comprised of almost six weeks. This quiz was given at the end of learning unit on electricity.

The Table 8 shows the summarized data.

Table 8 - Mean of multiple choice test.

	Mean	Size
Correct responses	11.98333	n = 60

Table 9 - Multiple choice test, student responses n = 60.

Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Correct responses	56	33	52	35	43	42	32	24	54	39	43	45	16	30	33	41	37	32	29

The use of multiple choice tests also provides data to compare the contrasting patterns with correct and distracting answers. The overall mean (11.98) is very low compared to the number of students (n = 60). The lowest score is for the question number 13, in which students were asked to pick between the "true" and "false" for a statement: protons in the outside orbit of the atom flow to produce electricity (Table 9). The highest score is for the first question response; in which 56 students have said "electricity is a form of energy". The statement "electricity is flow of electrons" has obtained 33 correct responses (Table 9). Almost half of the student population did not agree to it. In terms of understanding the use of electricity, 30 students have said "static electricity is more useful for our home appliances than current electricity". Also 33 students have agreed to "electricity is the only form of energy that is useful in our homes". When students had to answer "true or false" for the statement "electricity has close relation with the concept of atoms and electrons", 43 students picked the correct answer. For the multiple-choice test question: "the flow of electrons has close relation with the concept of electricity", 42 students picked this as a correct answer. In the question number 2, when students had to select an answer for "electricity is flow of..." 33 of them picked electrons, 10 of them picked batteries, 12 of them picked circuits (Table 9). Overall, around half of them were incorrect in their selection of answers. In the question number 4, students had to pick an answer for "current electricity is made up of. . . ." 4 of them "picked cars without gas", 35 of them picked moving electrons, and 16 of them picked insulation. Student concepts on electricity are in need of better learning opportunities. In order to see results from a multiple perspective those multiple-choice answers can also be seen in the light of other frameworks of data collection. Student writing samples also provide a reflection of what they understand about the concept of electricity (Table 10).

Table 10 - Lexical conceptual profile based on students' writing (n = 60, male = 29, female = 31).

Lexical conceptual profile (From students' writing) n = 60 , male 29, female 31			
Keywords	Word frequency	Absolute frequency (out of 1295)	Relative frequency (out of 227 words used)
1.Electricity, electric, electrical	93	7.1815%	40.9692%
2. Form	12	0.9266%	5.2863%
3. Energy	44	3.3977%	19.3833%
4. Flow/flowing	3	0.2317%	1.3216%
5. Conductor/conduct	5	0.3861%	2.2026%
6. Movement	1	0.0772%	0.4405%
7. Electron(s)	10	0.7722%	4.4053%
8. Atom(s)	5	0.3861%	2.2026%
9. Matter	0	0.0000%	0.0000%
10. Radiation	0	0.0000%	0.0000%
11. Electromagnetic	0	0.0000%	0.0000%
12. Power	4	0.3089%	1.7621%
13. Physical	0	0.0000%	0.0000%
14. Protons	2	0.1544%	0.8811%
15. Attraction	0	0.0000%	0.0000%
16. Particles	0	0.0000%	0.0000%
17. Charge(s)	3	0.2317%	1.3216%
18. Repulsion	0	0.0000%	0.0000%
19. Light	25	1.9305%	11.0132%
20. Heat/heating	5	0.3861%	2.2026%
21. Work	0	0.0000%	0.0000%
22. Machine	0	0.0000%	0.0000%
23. Battery/Batteries	6	0.4633%	2.6432%
24. Current	0	0.0000%	0.0000%
25. Wire(s)	9	0.6950%	3.9648%

3.4. Lexical-conceptual profile (student responses)

Students' writing work shows highest number of word frequency is 'electricity', 'electric', 'electrical' (relative frequency 93 or 40.9692%). The next highest group of frequencies is 'energy' (19.3833%), 'light' (11.0132%), and 'form' (5.2863%). It is notable that there is zero word frequency found in the students' writing work for the keywords: 'current', 'machine', 'work', 'repulsion', 'particles', 'attraction', 'physical', 'electromagnetic', 'radiation', and 'matter'. The absolute frequency for electrons is 0.7722% and for atom is 0.3861%. In the multiple choice test (Table 10), only 33 students picked the answer 'electricity is flow of electrons. In the written task that number is very low when compared for key-word frequency. The lower frequency of use for those key-words shows a large number of students tried to provide their understanding of the word electricity without linking to the flow of electrons and other science related terms. Students written work analysis indicates need for improving the way the concept of electricity is presented in the textbook and other ways of communication. Including reasoning in science education and promoting explanatory understanding in our textbooks is a growing need in our curriculum designs and curriculum resources preparation. A complete chart of frequencies can be seen in Table 10.

3.5. Student made pictures

Students were also encouraged to draw pictures to reflect their understanding of the word electricity. Out of all students only three students made pictures to support their text. Two pictures were made about the functions of a simple circuit (battery, bulb, wires). One student made picture about the generation of electricity.

The analysis in the previous discussion based on the study of Justi and Gilbert [17] and Harrison and Treagust [18] 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 [17, p.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 on Electricity [14] does not provide any model of atoms to explain the concept of electron flow. Another question remains to compare is about the elementary level science curriculum of Ontario. How well the concept of atoms is emphasized in the elementary level science? As many concepts of science discuss reasoning related to the concept of atoms. In the 21^{st} century it is of crucial importance to understand this fundamental concept behind many science related ideas.

4. Comparison of various framework results with research question

The 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 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" [14, p. 4]. Despite containing the linguistic attribute of cause-and-effect, the reasoning for the scientific phenomenon is not intended in this context. Student writing work also shows lack of use of keywords to provide explanatory understanding.

In the following passages some short quotes 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. [14, 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 [19] "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. [14, 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 [14, 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 [14, 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 [14, 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. [14, 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. [14, 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 [14, 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! [14, p. 5]

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

> Where Does Electricity Come From? [14, 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. [14, 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. [14, 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. [14, 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: [14, 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. [14, 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' [14, 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 [14, 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 [14, 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 [14, 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. [14, 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. [14, 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').

This study promotes explanatory models which can also be highly useful for the developing world science textbooks where science is primarily taught by this main source of learning. According to Venezky [20, p.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.

5. Summary and suggestions for further research

Explanatory understanding can be enriched with explanatory sentences and other mediums of communication. In view of the above discussion and analysis, research studies on textbooks can also collaborate with the process of textbook designing and exploring ways to promote explanatory understanding.

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 [21, p. 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 textbooks and curriculum outlines in light of the above conclusions. 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. For future research studies focus and learning resource preparation, there is a need to explore the effects of use of such processes in the wide range of educational media. There is 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.

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.

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 some observations of the frontline educator. 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. This study was conducted based on the Ministry of Education, Ontario science curriculum published in 1998 and the Electricity textbook [14] published to support it. Future studies can also reflect data on the new curriculum and the textbooks published to support it. The concept of atoms given across the Ontario elementary level science curriculum is of special importance for many science related concepts and their explanatory understanding. This research question can be studied further in the future studies from multiple frameworks.

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 [22]. 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 to collect more data for extended comparisons.

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. Perhaps future studies, similar or extended critical comparisons will enrich the research continuum for elementary level students.

References

[1] A. Peacock and H. Weedon, Research in Science & Technological Education **20**,185 (2002).

[2] F.C. Keil and R.A Wilson, *Explanation and Cognition* (The MIT Press, Massachusetts 2000), p. 281.

[3] L. Newton, D. Newton, A. Blake, and K. Brown, Research in Science and Technological Education **20**, 227 (2002).

[4] S.J. Gould, *The Hedgehog, the Fox, and the Magister's Pox: Mending the Gap between Science and the Humanities* (Three Rivers Press. New York 2003).

[5] R.S. Nickerson, American Journal of Education **93**, 201 (1985).

[6] J.R. Fraenkel and N.E. Wallen, *How to Design and Evaluate Research in Education* (McGraw-Hill, Inc., New York, 1993), p. 390.

[7] R.M. Luecht, *Cognitive Diagnostic Assessment for Education*, edited by Jacqueline P. Leighton and Mark J. Gierl (Cambridge University Press, New York, 2007).

[8] M.J. Chambliss and R.C. Calfee, *Textbooks for Learning, Nurturing Children's Minds* (Blackwell Publishers, Massachusetts, 1998).

[9] B. Berelson, *Content Analysis in Communications Research* (Free Press, New York, 1952), p. 18.

[10] Y. Lee, *How Do the High School Biology Textbooks Introduce the Nature of Science.* PhD Thesis, Faculty of Education, University of Houston, 2007, p. 20.

[11] O.R. Holsti, *Content Analysis for the Social Sciences and Humanities* (Addison-Wesley, Reading, 1969), p. 2.

[12] R.W. Weber, *Basic Content Analysis* (Sage, London, 1990), p. 9.

[13] M.A. Phillips, *Content Analysis of Sixth-Grade, Seventh-Grade, and Eight-Grade Science Textbooks with Regard to The Nature of Science.* PhD Thesis, University of Houston, 2006, p. 50.

[14] S. Campbell, D. Hayhoe, D. Herridge, L. Sander, J. Wiese, B. Williams and R. Wortzman, *Science & Technology: Electricity* (Addison Wesley and Pearson Education, Toronto, 1999).

[15] K.L. Alesandrini, Instructional Science **13**, 63 (1984).

[16] L. Anderson, in *Encyclopedia of Education*, edited by James W. Guthrie (New Yorkk Thomson Gale, 2003).

[17] R. Justi and J. Gilbert, International Journal of Science Education **22**, 993 (2000), p. 1006.

[18] A.G. Harrison and D.F Treagust, Science Education **80**, 509 (1996).

[19] A. Schlessinger, *Electricity, Physical Science in Action* (Schlessinger Media, Wynnewood, 2000) Video broacher.

[20] R. Venezky, *Handbook of Research on Curriculum*, edited by W. Philip (Jackson Macmillan Publishing Company, New York, 1992).

[21] C. Wallis and S. Steptoe, *How to Bring U.S. Schools Out of the 20^{th} Century* (The Time, New York, 2006), v. 12, p. 36.

[22] G. Giordano, *Twentieth-Century Textbook Wars: A History of Advocacy and Opposition* (Peter Lang, New York. 2003).