The effect of adjunct illustrations on Year 8 students' comprehension of scientific text

Jackie Knapp

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THE EFFECT OF ADJUNCT ILLUSTRATIONS ON YEAR 8
STUDENTS' COMPREHENSION OF SCIENTIFIC TEXT

By

Jackie Knapp BA Ed (Secondary)

A Thesis Submitted in Partial Fulfilment of the Requirement for the Award
of Bachelor of Education with Honours at the Faculty of Education, Edith
Cowan University

Date of Submission: 22nd November 1996
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Illustrations are present in the majority of Secondary Science textbooks. The type of illustration used and its purpose varies from text to text. The four most common forms of illustration are the photograph, hand drawing, line drawing and scientific abstract diagram. Some illustrations such as glossy photographs serve no other purpose than to attract the student to the text and motivate them to read. Others such as the scientific diagram present a lot of information in a condensed form and their purpose is to clarify concepts. Some of these more complex illustrations are often difficult to interpret especially for younger readers. The aim of this study was to investigate the effect that four forms of illustration had on Year 8 students' comprehension of the topic corrosion.

Seventy-six Year 8 students participated in this study. Each student completed a pre-test three weeks before the study. During the study each student was given a booklet containing four sections. Each section dealt with a sub-concept of corrosion and was accompanied by an illustration. Each booklet contained four different illustrations, a photograph, a hand drawing, a line drawing and an abstract scientific diagram. After reading each section the students completed three questions relating to the concepts covered. The third question assessed the students' interpretive and applied comprehension, which gave a more accurate assessment of comprehension. Data were analysed using ANCOVAs.

There was no statistically significant difference found in relation to any of the illustrations or questions. Line drawings yielded results that were close to being significantly different from the other forms of illustration. The possibility of further research on this form of illustration is discussed.
The analysis of the third question dealing with interpretive and applied comprehension in relation to the illustrations also produced results that indicate that it is an area for further research.
DECLARATION

I certify that this thesis does not incorporate, without acknowledgment, any material previously submitted for a degree or diploma in any institute of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person where due reference is made in the text.

Jackie Knapp
I acknowledge, the support and advice of my supervisor, Dr John Rowe. He has continued to give me encouragement to complete this study over a long period of time. I would also like to thank his family for contributing the drawings for this study.

I would also like to acknowledge, Dr Mark Hackling, who assisted me with this study in John’s absence.

I would also like to acknowledge and thank, Stephen who has stuck by me throughout this study and whose support has been invaluable.

Finally I would to thank the staff and students of the school for volunteering their time and efforts.
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CHAPTER ONE

Introduction

Background

Text books used in lower secondary science contain many forms of illustration. These illustrations can vary from photographs, drawings, line drawings and scientific diagrams. Each of these illustrations is different in the information that they present to the reader. Because there are many different forms of illustration and visuals available to students, the question is raised of which are most effective in helping the reader comprehend scientific phenomena and concepts.

Theoretical framework

Purpose of illustration

Illustrations can be viewed as another mode of communication within the classroom. Communication involves sending and receiving a message. The message can be in written or spoken form. Illustrations are included to support the written text and enhance this source of communication. They can clarify, expand or simply back-up what is written. When information is presented in more than one form the information has more chance of being remembered and retained. The illustration provides the reader with another form of representation that may be more easily memorised.

Several studies have demonstrated that illustrations are effective when presented with written text to enhance learning ( Holliday, 1975; Holliday & Harvey, 1976; Koenke & Otto, 1969; Purnall & Solomon, 1991 ). These studies focused on different forms of illustrations. So it can be said that illustrations as a whole are effective. The effectiveness of an illustration can be related to the purpose that it serves within the text.
Some text books contain many glossy coloured illustrations. These may or may not be directly related to the information presented in the text. Their main purpose is to motivate the reader or to sell the book (Holliday, 1990). The reader's attention is gained by the use of the illustration. This then leads them to read the accompanying text. If the illustration interests the reader then it is likely that the text will also interest them. The illustrations create an interest (Petterson, 1989). Flicking through a text the reader is attracted by the illustrations rather than the written word.

Illustrations can also be included as space fillers (Holliday, 1990). In the layout of a text space may need to be filled so that the book looks good and is set out in a pleasing way. The inclusion of an illustration can fill spaces and improve the appearance of the page layout.

Types of illustration

The purpose of the illustration may also determine the form of illustration that is used. One form of illustration may be more appropriate than another. Illustrations such as photographs provide real-life examples of phenomena or concepts discussed in the text. The reader constructs a mental image relating to the subject that is covered in the text. These images are usually based on the reader's prior knowledge (Osborne & Wittrock, 1985). This prior knowledge is stored within schemata. New information is integrated in terms of the existing schema and meaning is constructed. Sometimes the wrong schema is utilised to integrate the new experience or an alternate framework is used to interpret the information and a further misconception is generated.

The use of illustration bridges the gap between real-life and prior knowledge (Morriss & Stewart-Dore, 1984). With an illustration such as a photograph the example is seen and the image that is formed is correct.
Illustrations can also be used to clarify complex concepts that would take many pages of text to explain (Holliday, 1986). This is especially evident in the sciences. New content which is important and may be hard to understand can be illustrated (Petterson, 1989). To explain digestion may take many pages of text. An illustration of the human body indicating all the relevant organs would take less space and summarises a complex process. The illustration also provides the reader with a summary of the information to memorise and study from.

Audience for illustrations

Illustrations can also vary between texts depending on the audience for the text. The audience is sometimes not a priority when designing visuals for a text and so the reader's needs are overlooked. (Sless, 1984). The absence of consideration for the reader/audience often results in inappropriate illustrations being used. The illustration may be too difficult for the reader to interpret. At the other end of the scale the illustration may be too easy to interpret and serve no purpose at all. The complexity of the illustration needs to be matched to the audience. A photograph is easy to interpret, and usually presents no problem in understanding. Simplified illustrations like scientific diagrams are more difficult to comprehend. The information is presented in abstract form and initially may not make any sense. The reader needs to understand the conventions of a scientific diagram such as symbols and arrows, and be able to relate the diagram to what it represents. The information presented needs to be interpreted by the learner (Winn, 1988). If the learner does not have the knowledge and the skills then the information will not be processed or will be processed incorrectly.
**The problem**

In primary school, students are mainly exposed to photographs or hand drawings. Line drawings may have been viewed, as they are often used for blackboard work. The use of scientific diagrams is rare. Therefore these students are more familiar with the lifelike form of illustration. Lowe (1985) explains "the likelihood that the illustrations which they (students) were exposed to throughout their primary education typically involved different pictorial styles formats and intended functions from those encountered in high school science diagrams" (p. 10).

The introduction of the scientific illustration into texts may cause confusion and misinterpretation. The diagram may even be ignored because it is too difficult to understand, or looks too difficult. Because scientific diagrams are used to explain complex processes students may miss key information by ignoring them.

High school involves many changes for primary students. One of these is new texts and illustrations. The assumption that the students can cope with these abstract illustrations can cause problems for students.

**Rationale and significance**

The aim of this study was to compare the effect that various types of illustration had on students' comprehension of corrosion. Four types of illustration were used: a photograph, hand drawing, line drawing, and an abstract scientific diagram.

The study examined the four forms of illustration to determine if they were any more or less effective than each other in enhancing comprehension. Students in Year 8 need to be aware that to understand the scientific diagram the reader needs to examine the given information in more detail than in the less compressed forms of illustration (Lowe, 1986).
If students are not aware of this then another form of illustration may be more appropriate to enhance comprehension. Or the students should be taught strategies to analyse and interpret the scientific diagram. The scientific diagram provides much information but it may not be the easiest to access. Students need to be given opportunities to explore these visualised materials (Barlex & Carre, 1985). This however is not always possible. If students do not have the opportunities to explore the illustration then another form may be more appropriate.

The type of illustration selected will depend upon the concept being taught. Some subject areas lend themselves to particular illustrations. Corrosion was chosen for this research because four concepts discussed could be adequately illustrated using the four forms of illustration.

The effectiveness of visualised instruction is dependent upon many factors. Some factors discussed by Dwyer (1978) include, the type of visual used, students characteristics and the type of educational objective to be achieved. The findings from this study can only be relevant to the topic, the text, the characteristics of the illustrations, the students and the intended learning outcomes.

The study can be of assistance to textbook writers and teachers. To the teacher it can highlight that special emphasis must be placed on the understanding of new forms of illustration. If new forms of illustration are presented then the students may need to be given time to explore these and their particular characteristics. If an illustration is found to be more effective then it should be further examined and its usage emphasised.

To the textbook writer they need to be aware that the interpretation by the reader is not always the intended one (Grombrich, 1984).
Allowances may need to be made for the new scientific reader so that the interpretation is what is intended.

A gradual introduction to the scientific diagram may need to be incorporated into the text. More photographs may need to be included in the text. The cost involved in production of the illustration could be examined, to determine whether the most expensive is necessarily the best.

Students' comprehension was assessed to determine the effectiveness of the illustration. The focus was on the students interpretative and applied comprehension. This was assessed using open ended questions. Students working at the interpretative and applied level reflect on the information and think it through (Morris & Stewart-Dore, 1984). The question was provided so that students could demonstrate this reflection and think through. The intention was that understanding would be displayed rather than recall.

**Purpose and hypothesis**

The purpose of this study was to evaluate the effect of four types of adjunct illustration on Year 8 science students' comprehension of text regarding corrosion.

Three hypothesis have been proposed:

1. Type of illustration will have no effect on students' comprehension of text regarding the topic of corrosion.
2. Type of illustration will have no effect on students' comprehension of text in each of the four sections of the topic of corrosion.
3. Type of illustration will have no effect on students' applied comprehension of text for the topic of corrosion.
Definition of terms

The four types of illustration used in this study were photographs, drawings, line drawings and scientific diagrams. A brief description of each is given below.

Photographs usually provide a real-life example of a concept. The photograph does not usually clarify any of the concepts covered. Photographs do not have labels or arrows highlighting the major features.

Hand drawn illustrations are very similar to photographs. They are a hand drawn replica of a photograph. They have the same features and characteristics as the photograph. The use of shading is used to highlight features. Like the photograph no labels are used to highlight significant features.

Line drawings are simplified illustrations. Details that are not relevant are omitted. The topic of the line drawing can still be identified by the reader. Line drawings also include labels which can highlight concepts discussed in the accompanying text. For example a line drawing of the human digestive system would include labels identifying the main parts of the anatomy, but detail such as eyes, hair, arms and legs that are not relevant, have been removed.

Scientific diagrams are simplified and much of the irrelevant detail is omitted. "Scientific diagrams usually contain a concentrated form of information coded into a highly economical form in which all but the essentials are stripped away" (Lowe, 1985, p.9) The relationships between the elements included covered in these illustrations is more important than the realism. Their purpose is to teach about the relationships between concepts rather than the concepts themselves (Lowe, 1986).
CHAPTER TWO

Literature Review

Roles of illustration

Secondary science texts include various forms of illustration that serve a number of purposes. Duchastel (1978) categorised the functions that illustrations serve into three roles. The three roles are not mutually exclusive, an illustration can serve more than one purpose. Duchastel's three categories are attentional, explicative and retentional. Duchastel defines attentional as making "the text more interesting to pick up, more interesting to browse through and more interesting to read." (Duchastel, 1978, p.37). Attentional illustrations are included to grab the audience's eye and to sell the book. In many cases there is no educational benefit in these illustrations. These illustrations "are meant to motivate the reader, no more" (Siess, 1984, p.109). Many texts are guilty of including coloured glossy pictures purely for selling the book and they do not clarify any of the important concepts (Holliday, 1990). Photographs and drawings are the most common form of illustration defined as attentional.

Duchastel's second role of illustration is the explicative, which is defined as "explain a given aspect of the topic being presented or they add something that is not clearly expressible in words" (Duchastel, 1978, p.38). The explicative category can be further divided into seven sub categories, descriptive, expressive, constructs, functional, logico-mathematical, algorithmic and data display. These explicative illustrations can include line drawings, diagram charts and graphs. The explicative illustrations assist the text to clarify concepts and may further explain difficult concepts. Because illustrations often summarise information, they can contribute critical clues that may not be in the text or may be too difficult to explain (Holliday & Harvey, 1976).
The final role of illustration described by Duchastel is retentional. "This role is derived from theory and remains to be supported by instructional research," (p. 38). The illustration's "role is based on the established fact that the human capacity for memorising pictures is less degradable than memory for verbal information." (Pavio, 1975 cited in Sless, 1984, p. 106) It is assumed that the illustration will act as a prompt, in the same way that sub-headings work. The students will retrieve the illustration and then the text to accompany it (Duchastel, 1978). Illustrations at the end of the text can be included in this category. In their research on the effect of illustrations for low ability students Koran and Koran (1980) demonstrated that illustration at the end of the text allows the students to review and reorganise previously processed material.

Simply being there for decoration is of no use (Winn, 1988). Illustrations are effective if they draw attention to the main attributes of a concept (Tennyson, 1978).

Communication and illustration

Illustrations are a form of classroom communication. Within the classroom there is constant communication in various forms. The communication is basically "I to You about It" (Moffit & Wagner, 1983). The sender (I) communicates a message (It) to a receiver (You). It is intended that the message that the receiver gets is the same as the sender intended. This however is not always true, the message that the receiver interprets is not always the intended one.
The more forms that the message is presented in the more likely the intended message is received. Text accompanied by illustration provides the message in two different forms. It is "generally recognised that illustrations add a dimension to communication which, if not always essential, is at least desirable," (Duchastel & Wagner, 1979, p.20). The process of communication involves the interpretation of the message by the receiver. Any illustrations are also interpreted as is the accompanying text. There is no assurance that the message that the scientific illustrator wants to communicate is the one that the students will perceive (Wheeler & Hill, 1990). However some characteristics can enhance the communication value within the text:

1. the text should be easily decoded;
2. information in the illustration should be central to the text;
3. the illustrations should provide a different access to the text content;
4. the illustrations should be congruent with the text content; and
5. the illustrations should provide a spatial or schematic representation of the interrelations of text," (Schallart cited in Hayes & Readence, 1983, p.246). Therefore like any other form of communication illustrations must be appropriate to be effective.

Illustrations and language

The language encountered in scientific text is different from many primary school texts. The language in scientific texts is expository, mostly factual and presents a lot of information in a small space (Morris & Stewart-Dore, 1984).

A student entering Year 8 has to deal with a new form of language that is different from the story book language that is used in the primary school. Thus when illustrating a text consideration must also be taken of the language. New language and new illustration together may be too much.
The reader also has to cope with the language and style of the writer (Morris & Stewart-Dore, 1984). In choosing the illustration as a possible form of communication suitable illustration and text must be chosen to ensure that the right message is communicated. The text in many cases is difficult to understand so illustrations are included to support the text (Morris & Stewart-Dore, 1984).

Comprehension

Comprehension is a many step process and can be difficult to assess. It is therefore necessary to define comprehension and determine the aspect of it which is to be assessed. Johnston (1984) discusses comprehension as both a process and a product. Knowledge is stored within schemata, and to comprehend new information, ties must be made between the information and the relevant schema. The process of comprehension involves elaborating, modifying and integrating the schematic structures. Both conscious and unconscious strategies are used to make sense of the new information. It appears therefore to be a complex process and is difficult to assess.

Herber (cited in Morris & Stewart-Dore, 1984) developed three level reading guides to assist students to better comprehend text. To comprehend information a reader must locate, interpret and then use the information. This can be summarised as literal, interpretive and applied comprehension.

Scientific diagrams and the generative learning model

Osborne and Wittrock's generative learning model (1985) explains how students acquire knowledge. Their model can also be applied to the comprehension of scientific diagrams. Students use their prior knowledge to construct meaning from new information. They must make links between the stimuli and stored prior information (Osborne & Wittrock, 1985).
When new information is presented to students they make links between the new information and prior knowledge. Meaning is constructed due to the connection between the sensory input that is attended to and information from long term memory (Osborne & Wittrock, 1985). Making meaning is therefore an active process with links continually being made. Students come to school with their own prior knowledge and beliefs. These are often very different from the theories of science and the teacher. However to the student their views are sensible and useful and generally work when constructing meaning (Osborne & Wittrock, 1985). When the student's view differs from the scientific, problems can occur. The students can construct meaning incorrectly, or reject the science view believing theirs is the better view.

Scientific diagrams can present information in a form which is completely new to the student. If the illustration is too 'foreign' and the student cannot link it to any prior knowledge then the illustration may be ignored. This is more evident in the more abstract forms of illustration of which students have had limited experience. Because of their failure to understand the illustration, students will focus on the written text which is more familiar to them. Holliday (cited in Levie & Lentz, 1982) found that a text-plus-diagram treatment was no better than text alone. He concluded that the diagram was too formidable a decoding task and therefore the students paid little attention to it. Because the text was familiar to the students they focused upon that. If the students have no prior knowledge or understanding about scientific diagrams they may not use them to their full potential.

Another problem that can occur is misinterpretation of the illustration. It appears that scientific illustrations assume that students are aware of the conventions used in scientific illustrations (Wheeler & Hill, 1990). These conventions can include lines, arrows, the removal of irrelevant detail and simplification.
Students may not be aware of these conventions and so draw on prior knowledge to try and make sense of the illustration. The students look for familiar patterns and form images of what they believe is correct (Barlex & Carre, 1985). As a consequence students do not recognise the diagram for what it is.

Many students view diagrams globally and do not distinguish between the diagram and the model of the world that it represents (Hill, 1988). Students do not have the experience or exposure to diagrams to view them in the correct way. They do not have the correct skills to distinguish between the represented form of the diagram and its intended purpose (Wheeler & Hill, 1990). A typical diagram creates an easy to read abstract expression of logical relationships between concepts not a realistic view of the world (Winn & Holliday, 1982). Understanding diagrams requires certain mental skills. The effectiveness of a diagram depends upon what the student can perform as a result of studying the diagram and the students ability to identify the relevant information within the diagram (Winn, 1988). The diagram must be processed in some way. Diagrams may not be necessarily 'easier' for some students (Winn & Holliday, 1982). Students therefore need exposure to scientific diagrams and training in how to correctly use and interpret them.

The increased capacity of children to handle perceptual complexity comes with age (Travers, citied in Holliday, 1973). Therefore students in Year 8 may not have the ability to interpret scientific diagrams. French (citied in Holliday, 1973) found that 11 year old students preferred familiar visuals rather than more complex unknown types.
Other studies

Research into illustrations has had varied results. The general impression is that if illustrations are incorporated correctly they will facilitate comprehension. In 1969, Koenke and Otto carried out a study on the contribution of pictures to children's comprehension of the main ideas in reading. In their study three groups were examined:
a group with text and a specific relevant picture;
a group with text and a generally relevant picture; and
a group with text and no picture.

Comprehension was assessed by a spoken summary sentence of the main ideas of the text. The sentence was awarded a mark of 1 to 5 depending upon the level of understanding. A mark of 1 referred to recall of the facts. A mark of 5 indicating internalization of the material and a deeper understanding. They found that there was no significant difference between groups 1 and 2. However there was a significant difference between 1 and 2 compared to 3. Koenke and Otto tentatively concluded that 6th grade students who were exposed to the illustration scored higher on the sentence summary. They also stated that "as long as the pictures have general relevance to a topic their presence is likely to enhance main idea responses" (Koenke & Otto, 1969, p.301).

Holliday has done extensive research in the area of illustration. In 1975 he carried out a study on students' comprehension of auxins. Comprehension was assessed by a verbal 30 item multiple choice test which dealt with experimental situations similar to those covered in the topic. He concluded that "This study does demonstrate that a certain kind of pictures or illustration can significantly facilitate a form of verbal comprehension" (Holliday, 1975, p.79).
Holliday and Harvey (1976) investigated adjunct labelled drawings in junior high school. Again verbal comprehension was assessed using multiple choice questions. They found that there was a significant difference in favour of a text plus illustration in favour of text with no illustration. They concluded that "the findings of this study suggest that there is an overall positive effect in adding adjunct labelled diagrams to a science text" (p.4). Care must be taken not to over-generalise the findings on illustrations. Illustrations must be tested within the theoretical framework of the classroom and can be applicable to the practices of the science classroom (Holliday, 1974).

A limitation of research into text illustrations has been identified by Willows (cited in Peeck, 1987). Pictures can vary so much between researchers. Much of the research does not include an example of the illustration or pictures used. A picture is viewed as a picture by researchers but may not viewed in the same light by other researchers. It is therefore important to clarify what is meant by a picture or any other form of illustration.
CHAPTER THREE

Methodology

Participants

The participants of the study were Year 8 students. The students all came from one metropolitan school. The Year 8 students as a group have low literacy skills. Seventy-six students took part in the study. The students came from four different science classes at the school.

Design of the study

The treatment for the study was a reading task accompanied by illustrations. The reading task focused on the topic of corrosion. The topic of corrosion was presented in four sections, *Introduction to corrosion*, *Corrosion prevention*, *Metal coatings (galvanising)* and *Alloys*. The reading task was typed and presented to the students in booklet form. The booklet represented a chapter from a text and included the four sections above.

Each section was accompanied by an illustration. Four forms of illustration were used, a photograph, a hand drawn representation of the photograph, a line drawing and a scientific diagram. Each booklet contained four illustrations, one for each concept.
Four different booklets were produced A, B, C and D. The text for the booklets remained the same. The booklets differed in the form of the illustration used for each section (see Appendices 1 to 4). Figure 1 below clearly shows the four booklets and the illustration used in each booklet. These booklets were randomly assigned to the students within the four classes.

<table>
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<tr>
<th>SECTION</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>Introduction to corrosion</td>
<td>PHOTO</td>
<td>HAND DRAWN</td>
<td>LINE DRAWING</td>
<td>SCIENTIFIC DIAGRAM</td>
</tr>
<tr>
<td>Corrosion prevention</td>
<td>LINE DRAWING</td>
<td>SCIENTIFIC DIAGRAM</td>
<td>HAND DRAWN</td>
<td>PHOTO</td>
</tr>
<tr>
<td>Metal coatings (galvanising)</td>
<td>HAND DRAWN</td>
<td>PHOTO</td>
<td>SCIENTIFIC DIAGRAM</td>
<td>LINE DRAWING</td>
</tr>
<tr>
<td>Alloys</td>
<td>SCIENTIFIC DIAGRAM</td>
<td>LINE DRAWING</td>
<td>PHOTO</td>
<td>HAND DRAWN</td>
</tr>
</tbody>
</table>

Figure 1 Matrix showing the arrangement of the four booklets and illustrations used
The text

The booklet was presented to the students as a chapter from a textbook. Within this chapter the four conceptual areas of corrosion were discussed as separate sections.

The text was written by the researcher using various text books to obtain information and examples. The length of each section varied from 200 to 300 words with the first two sections, *Introduction to corrosion* and *Corrosion prevention* being longer than *Metal coatings* and *Alloys*.

The text was shown to a peer for analysis of the difficulty for Year 8 students. It was agreed that the text became more difficult through the four sections, with the last section on *Alloys* being the most difficult. This difficulty arose from the subject material being covered. The initial section *Introduction to corrosion* was easy to understand and did not involve any difficult sections. The section on *Alloys* however discussed more complex scientific ideas and was more difficult.

Assessment tests

Comprehension was assessed by a three-item test for each section. The test was given to the students directly after they had read the text relevant to the conceptual area: *Introduction to corrosion, Corrosion prevention, Metal coatings* and *Alloys* (see Appendices 5 to 8).

The first question of the test was multiple choice. The answer for this question could be found easily in the text. The students did not require an understanding of the concepts to answer this question. This question was at the literal comprehension level, where the students had to identify the correct
information within the text (Morris & Stewart-Dore, 1984). The first question was the least difficult of the three. Its purpose was to relax the students and introduce them to the topic. This question was allocated one mark.

The second and third questions were short answer questions. The second question was easier than the third. The answer could be found in the text, but required the student to have some understanding of the concepts covered to achieve the correct response. It introduced the idea of writing an extended answer and required students to look slightly beyond the text. This question was at the interpretive comprehension level, where the students had to look beyond the written text and make inferences about the information presented (Morris & Stewart-Dore, 1984). This question was allocated two marks.

The third question required the students to use interpretive and applied comprehension (Morris & Stewart-Dore, 1984). The concept covered came from the text, but it was applied to a new situation. This third question gave an indication of whether the students understood the text, rather than just read it. The third question required the students to think and not simply copy from the text. It was this third question that gave the best indication of students true comprehension of the topic of corrosion. This question was allocated three marks.

A marking key was devised and used to mark the tests (see Appendix 9). A selection of responses and the marking key were given to a peer to mark. The markers scores were analysed using a Pearson r to determine the inter-rater reliability. A correlation coefficient of 0.82 was calculated. (Mean scores 3.5 and 2.6)
Variables

The independent variable in this study was the form of illustration. The illustrations varied from booklet to booklet.

The text was a controlled variable as it remained constant through the study. The students group was also a controlled variable as it remained constant. In addition every student was exposed to all four forms of illustration so this too remained constant.

A comprehension test was administered to determine the effect of each illustration. The comprehension test acted as the measure of the dependent variable. The results from the test determined if there was any change due to the differing illustrations.

Pilot study

A pilot study was carried out with ten Year 8 students who were asked to underline any words for which they did not know the meaning. They also highlighted sentences that did not make sense to them. These sections were re-worked and in the second piloting it was found that students could understand the majority of the text.

During piloting the text was shown to the students' teachers for assessment. They also suggested changes in terms of language. Any areas or concepts that may have been too difficult for students were also examined. These areas were re-worked so that better understanding could take place. The readability of the four pieces was analysed using the FRY readability estimate (1968) as explained in the Syllabus for Lower Secondary Science. It was found that the readability of the four sections was at Year 5/6 level. Thus it was appropriate for the group of students chosen.
Procedure

The study took place during a 64 minute science period at the school. Two sessions were spent with the students.

The first session was during the last week of school Term 3. The first session was a pre-test, carried out to determine the students prior knowledge on the topic of corrosion. Students were given the answer booklets without the text. They were instructed to complete as many of the questions that they could. A time limit of 10 minutes was given, which was sufficient time for all the students to complete the questions that they could do. Students were asked to place their names at the top of the paper. This was so that their pre and post test scores could be compared.

The main part of the study took place two weeks later after the school holidays. Again it was during school science class time. Students were given two booklets, one contained the text and the other was the answer booklet. The booklets were numbered A, B, C or D depending upon the order of illustration. All booklets covered the same section on the same order. The conceptual difficulty also increased as they progressed through the four sections: Introduction to corrosion, Corrosion prevention, Metal coatings, and Alloys.

During piloting, times were recorded in which all the students could read the text and complete the questions. It was also found that the students tended to look at the questions then read the text to find the appropriate answer, rather than read the text first. In the study the students were given set times to read the text and answer each section of the test.
For each section the students were given five minutes to read the text and then eight minutes to complete the questions; this was more than sufficient time for the students to complete the work. During the five minutes reading time no student was able to write. During this time the classroom was patrolled to ensure that students were not looking at the questions and were reading the correct section.

At the completion of the five minutes reading time students were able to answer the questions. Students who finished early were instructed to re-read the text and check their answers. After eight minutes answering time the students were instructed to turn over to the next section and begin reading that without answering the next set of questions.

This cycle continued until all four sections had been covered. Students were instructed to place their names at the top of the paper. This allowed scores to be compared from pre and post-tests. Also, because the students put their name on the paper it gave them some ownership so they had responsibility for what was written and it was thought that they would take the study more seriously.

*Analysis of data*

Students pre and post-test scores were matched. Any student who took part in only one of the two studies was not included. Both the pre and post-tests were marked according to the marking key. All the raw scores for each student were matched and the scores for each question and the totals were tabled.

SPSS for Windows was used to carry out the statistical analysis. Three analyses were performed, each relating to the research questions. ANCOVAs were used for the analysis of all the research questions. ANCOVAs
were selected because these would adjust the post-test scores by taking into account the differences in the pre-test scores. This was done reduce variance within the group (Gay, 1985).

The first analysis examined the effect of the type of illustration on students' comprehension. An ANCOVA was carried out on the mean scores for the four sections for each student. The scores for each form of illustration were compared to determine if there were any significant differences between the four forms of illustration.

The second analysis examined the effect of illustration on students' comprehension of the four sections of corrosion. Four ANCOVAs were performed. One for each of the sections. (ie. Introduction to corrosion, Corrosion prevention, Metal coatings and Alloys). The scores for each form of illustration per section were examined.

The third analysis focused on the third question. Five ANCOVAs were performed. One for each of the sections and one for the total score across the four sections ie. the topic of corrosion.
CHAPTER FOUR

Results

Introduction

The student scores were analysed at three levels. The first analysis examined the scores for each form of illustration over the entire topic of corrosion. All of the students' data were used for this analysis. Test scores for the four sections were summed and a mean score was calculated for the four types of illustration for the topic of corrosion. The mean scores for the four forms of illustration were then compared using an ANCOVA. This analysis was to determine the effect of the illustrations in relation to the topic of corrosion. These data were used to test the first hypothesis.

The second analysis examined the four sections of the corrosion topic separately. Scores were summed within the four sections i.e. Introduction to corrosion, Corrosion prevention, Metal coatings and Alloys. A mean score for each form of illustration with the section was calculated. These mean scores were then compared using ANCOVAs. As each section was examined individually, smaller groups were used. This analysis, like the first examined the effect of illustration type on students' comprehension within each section of the topic.

The third analysis focused on the third hypothesis. This concerned the applied comprehension. Scores for the third test question on each section were summed within each section of the corrosion topic. Four ANCOVAs were performed to see if there was a significant difference in the applied comprehension between the four types of illustration.
Hypothesis one

"Types of illustration will have no effect on students' comprehension of text regarding the topic of corrosion."

This analysis involved all the scores for the whole topic of corrosion. Scores for each form of illustration were summed from the four sections. All students results were used for this analysis (n=76). Table 1 summarises the results.

Table 1 Mean pre and post test comprehension scores for the text illustrated with four types of illustration (n=76)

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test M</th>
<th>Pre test SD</th>
<th>Post test M</th>
<th>Post test SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photograph</td>
<td>0.51</td>
<td>0.79</td>
<td>1.87</td>
<td>1.61</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.61</td>
<td>0.91</td>
<td>1.99</td>
<td>1.44</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.60</td>
<td>0.85</td>
<td>2.42</td>
<td>1.73</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.63</td>
<td>0.81</td>
<td>1.89</td>
<td>1.46</td>
</tr>
</tbody>
</table>

An ANCOVA revealed that the types of illustration had no statistically significant effect on students' comprehension, \( F (3,299) = 2.03, p=.11 \). Therefore the null hypothesis is accepted at the \( p<.05 \) level.
Hypothesis two

"Type of illustration will have no effect on students' comprehension of text in each of the four sections of corrosion."

This analysis focused on the four sections of corrosion. Results from the four sections were examined individually to determine if there was any effect due to illustration type on comprehension of text by section. The population sample is therefore smaller (n=19) for each section. ANCOVAs were used in all cases with an alpha level of p<.05. Tables 2 through 5 summarise the results.

Table 2. Mean pre and post test comprehension scores for the section, Introduction to corrosion, illustrated with four types of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th></th>
<th>Post test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.26</td>
<td>0.56</td>
<td>1.42</td>
<td>1.30</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.42</td>
<td>0.51</td>
<td>1.82</td>
<td>1.71</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.52</td>
<td>1.02</td>
<td>2.57</td>
<td>1.71</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.36</td>
<td>0.6</td>
<td>1.84</td>
<td>1.53</td>
</tr>
</tbody>
</table>

The type of illustration had no significant effect on students comprehension of this section of the text, F(3,71)= 1.37, p = .26.
Table 3. Mean pre and post test comprehension scores for the section, *Corrosion prevention*, illustrated with four types of illustration (n=19)

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.42</td>
<td>0.84</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.47</td>
<td>0.70</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.74</td>
<td>0.87</td>
</tr>
</tbody>
</table>

The type of illustration had no significant effect on students' comprehension of this section of the text, $F(3, 71) = 1.48, \ p = .23$.

Table 4. Mean pre and post test comprehension scores to the section *Metal coatings*, illustrated with four type of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.58</td>
<td>0.61</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.21</td>
<td>0.41</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.68</td>
<td>1.01</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.79</td>
<td>0.79</td>
</tr>
</tbody>
</table>

The type of illustration has no significant effect on students' comprehension of this section of the text, $F(3, 71) = .92, \ p = .44$. 
Table 5. Mean pre and post test comprehension scores for the section, Alloys, illustrated with four types of illustration (n=19)

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.79 1.03</td>
<td>1.83 1.84</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.84 1.16</td>
<td>1.68 1.29</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.74 1.16</td>
<td>2.21 1.69</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.63 0.95</td>
<td>1.63 1.16</td>
</tr>
</tbody>
</table>

The type of illustration had no significant effect on students' comprehension of this section of the text, F(3.71) = 1.51, p = .22.

Analysis of data for all four sections

The type of illustration had no effect on students' comprehension of the text. Therefore the null hypothesis is accepted in all cases at the p < .05 level.
Hypothesis three

"Type of illustration will have no effect on students' applied comprehension of text in each of the four sections of the topic of corrosion."

To determine if the type of illustration had any effect on interpretive and applied comprehension five ANCOVAs were performed. One for the total scores (topic of corrosion) and four dealing with the sections of the topic. The alpha level used was p<.05. Tables 6 through 10 summarise the results.

Table 6. Mean pre and post test scores for question three (applied comprehension) for the text illustrated with four types of illustration (n=76).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test M</th>
<th>Pre test SD</th>
<th>Post test M</th>
<th>Post test SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photograph</td>
<td>0.32</td>
<td>2.31</td>
<td>0.74</td>
<td>1.84</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.14</td>
<td>0.45</td>
<td>0.42</td>
<td>1.29</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.13</td>
<td>0.47</td>
<td>0.79</td>
<td>1.69</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.07</td>
<td>0.32</td>
<td>0.53</td>
<td>1.16</td>
</tr>
</tbody>
</table>

Type of illustration had no significant effect on students applied comprehension of the text, F (3,299) = 2.43, p = .06.
Table 7. Mean pre and post test scores for question three (applied comprehension) for the *Introduction to corrosion* section illustrated with four types of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.26</td>
<td>0.73</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.05</td>
<td>0.23</td>
</tr>
</tbody>
</table>

There was no significant difference between pre and post-test scores for this section, $F(3, 71) = .83, p = .48$

Table 8. Mean pre and post test scores for question three (applied comprehension) for the *Corrosion prevention* section illustrated with four types of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.16</td>
<td>0.50</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.21</td>
<td>0.53</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.10</td>
<td>0.31</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.16</td>
<td>0.50</td>
</tr>
</tbody>
</table>

There was no significant difference between pre and post-test scores for this section, $F(3, 71) = .21, p = .89$
Table 9. Mean pre and post test scores for question three (applied comprehension) for the Metal coatings section illustrated with four types of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>1.05</td>
<td>1.03</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.00</td>
<td>1.16</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.10</td>
<td>0.65</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.63</td>
<td>0.95</td>
</tr>
</tbody>
</table>

There was no significant difference between pre and post-test scores for this section, $F(3, 71) = 1.51, p = .22$

Table 10. Mean pre and post test scores for question three (applied comprehension) for the Alloys section illustrated with four types of illustration (n=19).

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Photograph</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Hand drawn</td>
<td>0.32</td>
<td>0.67</td>
</tr>
<tr>
<td>Line drawing</td>
<td>0.05</td>
<td>0.67</td>
</tr>
<tr>
<td>Diagram</td>
<td>0.05</td>
<td>0.23</td>
</tr>
</tbody>
</table>

There was no significant difference between pre and post-test scores for this section, $F(3, 71) = 1.48, p = .23$
CHAPTER FIVE
Discussion

It can be seen from the results that the form of adjunct illustration had no significant effect on Year 8 science students' comprehension of text regarding corrosion.

This was a preliminary study that broadly examined the effect of adjunct illustrations on students' comprehension of text. From this study ideas for further research can be identified. A lack of significant results shows that further study should be more specific and discriminatory. The use of a more powerful treatment which focuses on the illustration and its effect is desirable. In addition to this, an instrument that is more detailed and sensitive is also needed. Differences between the effects of the illustration need to be clearly identified. A more sensitive instrument would be able to identify areas that a study as broad as this one would be unable to do.

Although there were no significant differences, when the data are examined some patterns can be identified. These patterns can be used as focus areas for further research. For the first hypothesis the results are not significant but the high F number, 2.03 and low p value .11 indicate that the results do tend towards significance. When each type of illustration is examined it can be seen that the line drawing has the highest post-test comprehension score.
If the line drawing results are examined across all of the sections of corrosion in most cases the post test scores for the line drawing are higher than for the other forms of illustration. It appears that the line drawings had the most effect. The line drawing can be described as half-way between the photograph and the diagram. The subject of the illustration is still readily identifiable, however a lot of the irrelevant detail has been removed. Simple pictures seem sufficient to enhance comprehension. Overly detailed or artistic pictures are not necessary to facilitate comprehension (Readence & Moore, 1987). The line drawings also include labels. Labels can be viewed as characteristic of diagrams. The combination of the realism and labels appears to have the most impact on the students. The realistic element makes the illustration more comprehensible and the labels draw attention to the main scientific content. The line drawing is simple, uncomplicated and focuses directly on the textual content.

The third analysis on the students applied comprehension also produced results that tended towards significance. A \( p \) value of .06 indicates that the results were close to significance.

The students did not answer the questions as expected. This originates from the problem of them not reading the text properly. The questions were intended to test the students comprehension. However from the student responses in some cases it tested their ability to extract and copy information from the text. The inclusion of the third question was to overcome this.

The use of the students own words and expansion of their ideas generally demonstrates an understanding (Anderson, 1972). The third question gave the students the opportunity to demonstrate their understanding. The first and second questions did not assess comprehension as well as the third.
As Anderson (1972) explains, "answering a verbatim question cannot be taken as evidence of comprehension" (p. 150). So one cannot assume that students who have copied from the text have any comprehension at all.

A possibility to overcome this is to have students read the text and then remove the text before the questions are answered. This way the problem of students copying straight from the text is overcome. Any answers are their own words and would be a truer indication of their understanding of the text. However the removal of the text introduces other variables which would need to be taken into account. If students are aware that they will be required to answer questions after without the text this would place extra pressure on the students. They would be more concerned reading and trying to memorise and predict questions rather than understanding what they are reading. For lower literacy groups such as the one used it would become a study of literacy levels rather than understanding. If they experience difficulty with understanding the content initially then answering questions without the text would be extremely difficult. If the text was to be removed a verbal test would be more appropriate. The subject could read the text and then verbally summarise what they have read to the researcher. This verbal summary would demonstrate understanding and also allow the subjects to review what they have read and make sense of it. Verbal questions could follow where comprehension and understanding could be investigated more thoroughly.

The questions focused on the written text. This was necessary as to have questions which directly related to information presented in some of the illustrations could disadvantage groups. Each illustration for each group was different therefore the questions had to relate to the text which was common to all groups.
The effect of the illustration could therefore be minimal due to the emphasis on the text. Dwyer (cited in Levie & Lentz, 1982) carried out a study on illustrated and non-illustrated texts. In his study he also made mention of the text dependence of the questions. He comments that the information tested was mostly text information. The difference between the two groups was therefore expected to be and was slight. In a study such as this the problem is difficult to overcome as questions cannot directly relate to the illustrations unless they are very similar.

**The ability of the learner**

The student reading the text needs the ability and background to work through the illustrations especially the scientific diagram. The success with which the visualisation of the content will facilitate the acquisition of knowledge is related to the individual's level of perceptual and associative learning (Dwyer, 1978). If the student does not have a high level of perceptual and associative understanding then the illustration will not facilitate learning. It would be assumed that the students in this study are at the level where they can correctly interpret a photograph but may have trouble with a scientific diagram. The scientific diagram needs to be introduced when students have the ability to correctly utilise them to facilitate learning.

Koran and Koran (1980) in their study of lower ability readers concluded that for different sub groups the effects of the pictorial adjunct may vary. Therefore different groups of learners may make more sense from different forms of illustrations. It cannot be assumed that all readers are at the same stage, or below the same sub group. Holliday and Harvey (1976) also comment saying that certain adjunct illustrations affect learners in different ways.
The learners reasons for using illustrations may also vary. Different forms of illustration may be more appropriate for different groups of students. A line drawing may be effective for one student and a diagram for another. This depends upon the students ability and also what information they are seeking from the text. The personal nature of what appeals to the individual and their interests is also a possible variable for the effectiveness of the illustration. A student may be able to draw information from a diagram and interpret the information given. Another student may be able to draw the same information from a drawing and gain the same understanding. Any differences of this nature are not seen in this study. The differences may have been so slight and the analysis would not have identified these differences. Discussion with students may identify personal difference. Having them identify what illustration they preferred and how they obtained information from the illustration would give an insight into the students' minds and the processes they go through to gain understanding.

**Student answering techniques**

From personal observations and experience students tend not to read text when they are given questions. They first look at the questions to be answered and then look for the answers in the text. In this study the students were given reading time to try and overcome this problem. Many students still wrote answers during the reading time. Some read the questions first and then read the text seeking out the answers to the questions. Some text books are guilty of encouraging this type of approach. Many of the answers to the questions at the end of the chapter are highlighted throughout the text by bold print, italics or the use of boxes. The text design may distract from the illustration. Although this is not directly related to this study, its effect did impact on the results obtained. These students do not read for the sake of reading, because of low literacy skills. Answering the questions was their motivation for reading. They need another motivation.
The focus on education is towards the verbal or written literacy. Therefore students are not trained to accept the visual aspect of text. From the beginning of their schooling students are educated to accept the verbal literacy and tend away from the visual literacy (Ingpen, 1975). So many students are under the impression that the main content of the text is what is written and not what is illustrated. This is evident in this study where it appears that many of the students paid little or no attention to the illustration and focused on the written information. The education that these students appear to have received is that the answers to the questions are the most important. If one can get these right then the text is understood. It is therefore difficult to assess for the differences in the illustrations when their impact on the students was more than likely minimal.

The use of visuals for communication and understanding is a complex task. Petterson (1989) discusses ways in which visuals can be designed so that they are a useful information tool. The use of a visual in a text book involves a long and lengthy process of deciding firstly the appropriate visual, where to place it within the text, what references will be made to it and importantly what its purpose will be within the text. It is not simply a matter of choosing a picture and placing it in a free space. Instructional designers need to look at the purpose of the illustration, the context, the text format, content and graphic execution (Petterson, 1989).

While this may have had little effect on the study, it needs to be noted that the construction of the text is dependent on many factors. The placement and orientation of the illustrations may have had just as much effect as the illustration itself. In a more detailed study these factors could be taken into account. While the realism in terms of the content was considered none of the others were. For example the illustrations were put at the end of the text. It was
not considered whether they may have been more appropriate within the text, where they may have been noticed more by the reader.
CHAPTER SIX

Conclusion

The study found that there was no significant differences in students text comprehension bought about by the use of different forms of adjunct illustration. It did however highlight some facets of illustration, questioning and answering techniques that may be suitable for further research.

Limitations of the study

The study covered only a small population of Year 8 students. This places limitations on the study in terms of generalisations that can be drawn from it. With a larger population there may have been more variety in the results due to a larger range of student responses. The results of this study are therefore only specific to the school and the year group where the study was conducted. The academic ability of these students was average or below, and the topic chosen was difficult to understand. Many of the students did experience difficulty understanding the concept of corrosion, especially the metal coatings and sacrificial metals. The topic of corrosion is not usually taught until Year 9 in most Western Australian schools in a unit entitled Chemical Change (Education Department of Western Australia, 1987). It was a topic that many students would have been exposed to in the same detail that it was in this study.

The nature of the students' responses is also a limitation of the study. Written responses are the easiest to analyse and record. However students may have had more understanding than they demonstrated in their written response. The students were more concerned about having something written
down rather than demonstrating their understanding. Spoken responses may have been more appropriate so that students could express themselves fully.

Further study

The results of the study do tend towards significance indicating that further research is possible. Research into the effect of line drawings is a possibility. Line drawings stood out as having the most impact on the post test scores. Further research could deal with a comparison of line drawings and other forms of illustration with the focus on the line drawings. The use of labels and arrows in line drawings is also another possible avenue for further research. This would determine if the realistic detail of the illustration is responsible for improved comprehension or the presence of arrows and labels highlighting the main features of the illustration.

The results for the third question (Table 6) are the closest to significance so questions dealing with applied comprehension may be more appropriate. In relation to this, students may need more experience at these types of questions. Morris and Stewart-Dore (1984) suggest using one guide at a time and not trying to teach all three in one setting; beginning with literal comprehension then interpretive comprehension and finishing with the applied comprehension after students have fully understood the first two. If students have had experience at looking for the critical clues in text and extracting information, then their answers to the applied comprehension type of questions would be more valid. Most schools in the Western Australian government system are now using *Stepping Out* (1995) strategies. Many of these strategies are related to the ERICA model (Morris & Stewart-Dore, 1984). A similar study carried out in a school that is using *Stepping Out* and has been using it for some time would be appropriate to assess for this type of comprehension. The students would have good experience at using the
Stepping Out strategies for extracting information effectively. Therefore any differences could be attributed to the use of the illustrations as students could effectively gain information from the text.

Students also need to be trained to read and understand adjacent illustrations prior to the testing. Once students are aware of the usage of the illustrations and experienced at obtaining information from them then a study could be carried out to determine the effect on students' comprehension. A longer term study could focus around educating students to use visuals and the effect that the education has on their usage of visuals in text.

Implications for teachers

Students need to be aware of the use of illustrations use them more critically. Teachers need to be aware also and give instruction on how to use illustrations. as Readence and Moore, (1981) explain "It should not be assumed that readers will automatically use pictures to aid their comprehension, after all, some pictures are placed in the text only for motivational purposes. Teachers can help improve students visual literacy by becoming aware of when pictures can help comprehension and by pointing out pertinent features of those pictures that will accomplish that purpose for readers" (p. 220)

Because students tend to ignore illustrations or not realise their effectiveness there is a need for some formal training. Teachers need to show students examples of good illustrations that will enhance their comprehension. Students should also be exposed to examples of bad illustrations that are included as space fillers or for motivational purposes. Students need to be critical of illustrations, by identifying those that serve a purpose and are relevant to the text. They need to be educated away from this attitude and use
the illustrations effectively. Students believe that all the relevant information is in the text (Barlex & Carre, 1985).

When students are first exposed to new illustrations, especially diagrams, some explanation needs to accompany them. Students need to realise that most written explanations have diagrams to help (Derwanika & Schmich, 1991). They need to understand these illustrations. The text itself needs to incorporate the use of illustration. There needs to be a connection between the illustration and the written text.

Sless. (1981) in his discussion on photographs makes the following points, "unless the context in which they are used offers sufficient guidance as to their use, most students will presume that they have an attentional role and will treat them as only incidentally relevant to learning" (p.10). If students have this attitude towards photographs then it can easily be transferred to other forms of illustrations. If photographs are irrelevant so are all other forms of illustration.
REFERENCES


Education Department of Western Australia. (1981). *Syllabus for lower secondary science*. Perth: Education Department of Western Australia

Education Department of Western Australia. (1987). *The unit curriculum: Science*. Perth: Curriculum Branch Education Department of Western Australia

Education Department of Western Australia. (1995). *Stepping out*. Perth: Education Department of Western Australia


Chapter 5

CORROSION

Introduction to corrosion

The corrosion of metals is a problem which costs Australian industries millions of dollars each year.

Metals are rarely found in their pure form. Most metals in nature occur as substances called oxides and carbonates. An oxide is the metal chemical combination of a metal and oxygen. Metal oxides are more stable than pure metals. The metal oxides that are found in nature are called ores, for example iron ore is iron oxide. In industry the oxides are processed to produce the metal that you see around you every day.

Corrosion is the process by which the metals return to their natural, stable, state as an oxide.

Corrosion is the breaking down of the metal due to a chemical reaction with oxygen in the presence of water. Rust is the most common form of corrosion. Rust is due to the corrosion of iron. The rusting of iron involves the iron reacting with the oxygen from the air in the presence of water. The new substance which is formed from this reaction is called iron oxide or more commonly rust.

\[
\text{iron} + \text{oxygen} + \text{water} \rightarrow \text{iron oxide (rust)}
\]
Figure 5.1 Corrosion of iron nails is a common problem.

Once iron has began to rust it will continue to rust. This is because the initial piece of rust provides a site for the chemical reaction to continue occurring. Rust is also very porous and water and oxygen can pass through it to the iron underneath so that the process continues.

Because it is porous rust has a larger volume than the iron that it originated from. Objects that have rusted tend to be larger than they were when they were a pure iron.

This expansion can be dangerous. Pipes, if they burst, in large factories can cause thousands of dollars damage. Rust is weaker than pure iron. Rusted objects are unable to serve the purpose for which they were manufactured. Bridges, made from iron may rust. The bridge would not be as strong and would not support the weight of cars and so would collapse.
Corrosion prevention

The corrosion of metals is dangerous and expensive. Builders of metallic structures design various methods to prevent or slow the corroding process.

Some metals react easily with oxygen and water. Metals such as potassium and sodium react vigorously with water. Other metals such as gold and platinum are not very reactive at all. How easily a metal corrodes is related to how reactive it is. A highly reactive metal corrodes easily whereas a not so reactive metal will hardly corrode at all. Metals can be arranged into a list called the Activity Series. This is a list of metals in the order of how reactive they are. Metals at the top of the list are very reactive, metals at the bottom are less reactive.

Here is an example of some metals in the activity series:

sodium
magnesium
aluminium
more reactive
zinc
more easily corroded
iron
nickel
lead
copper
silver
less reactive
platinum
less easily corroded
gold

The least reactive metals, such as gold, would be more appropriate for structures because they hardly corrode at all. These metals are also very expensive and inappropriate to build from.
The reactivity of a metal can be used for corrosion prevention.

When two metals are in contact with one another, the more reactive metal will corrode. The other metal will hardly corrode at all. This behaviour of the metals is used as a form of corrosion prevention.

Many ship hulls are made from iron. Because of the constant exposure to water the hull corrodes. Zinc is more reactive than iron and corrodes easily. If a block of zinc is attached to the iron hull the zinc will corrode. The iron, because of the presence of the zinc will not corrode. After all of the zinc has corroded, then the iron will begin to corrode. The zinc blocks need to be replaced regularly to ensure the iron hull will not corrode. The blocks of zinc used are a lot smaller than the large hull. It is a lot cheaper to constantly replace these zinc blocks than an entire ship's hull.

Figure 5.2 Zinc blocks used for corrosion prevention can be seen on the hull of this ship.
Metal Coatings

The corrosion of some metals is helpful rather than damaging. The surface of these metals undergo corrosion and form a metal oxide layer. Unlike other metals where corrosion continues from the initial site, the metal does not continue to corrode. The metal oxide layer remains stable and protects the metal underneath. No further corrosion can occur because oxygen and water cannot pass through the protective oxide layer.

Aluminium is a metal that forms a oxide layer. It is for this reason that aluminium is used for lightweight outdoor structures.

The oxide layer is also useful to protect other metals. A common form of corrosion prevention is called galvanising. Galvanising involves coating a metal with another metal. The metal that is used as a coating is one that forms its own protective oxide layer. When exposed to oxygen and air the surface of the coating metal chemically reacts and a protective oxide layer is formed. The oxide layer and the metal coating prevent exposure of the metal underneath to water and oxygen. Therefore the metal underneath does not corrode.

![Microscopic picture of steel coated with zinc](image)

**Figure 5.3** A microscopic picture of steel coated with zinc. (X 200)
An example of galvanising is galvanised iron used for roofing. The iron is coated with a layer of zinc. Zinc is a metal that forms a oxide layer. Zinc is also higher than iron on the activity series. If the zinc oxide layer is scratched the zinc layer will corrode. The zinc layer acts in the same way that the zinc blocks do on the hull of a ship, and corrodes before the iron.
Alloys

The word alloy comes from the French word *aloi* meaning 'to mix' or 'to combine'. Alloys are mixtures of two or more metals. Alloys take advantage of desirable properties in metals. The properties of an alloy originate from the metals that are mixed to produce it. The alloy is superior to the metals that constitute it. Sometimes non-metals are added to a metal to improve its properties as well.

Mixing small amounts of other metals has marked effects on the produced alloy's properties.

Alloys are created and used for different purposes. There are over 2000 different types of alloys. Each alloy has specific properties which are related to its use.

![Diagram of stainless steel composition]

*Figure 5.4 The structure of stainless steel.*

One of the properties that can be desirable in an alloy, is resistance to corrosion. Stainless steel is a good example of this. Stainless Steel is an alloy of chromium, nickel and steel. Steel is iron with a small amount of carbon added, the carbon increases the strength of the iron. Chromium and nickel are metals that do not corrode easily. The addition of the chromium and nickel greatly increase the resistance of the steel to corrosion.
The corrosion resistance of the steel alloy depends on the amount of chromium that is added. As more chromium is added the corrosion resistance increases. For example if the alloy contains 12-14% chromium then it usually used for kitchen utensils, so they remain shiny for decorative purposes. In very high quality car exhaust mufflers and in factories where high temperatures and dangerous chemicals are used the stainless steel contains 25-30% chromium. In these situations the corrosion resistance needs to be, and is, very high.
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Corrosion is the process by which the metals return to their natural, stable, state as an oxide.

Corrosion is the breaking down of the metal due to a chemical reaction with oxygen in the presence of water. Rust is the most common form of corrosion.

Rust is due to the corrosion of iron. The rusting of iron involves the iron reacting with the oxygen from the air in the presence of water. The new substance which is formed from this reaction is called iron oxide or more commonly rust.

\[
\text{iron + oxygen + water} \rightarrow \text{iron oxide (rust)}
\]
Once iron has begun to rust it will continue to rust. This is because the initial piece of rust provides a site for the chemical reaction to continue occurring. Rust is also very porous and water and oxygen can pass through it to the iron underneath so that the process continues.

Because it is porous rust has a larger volume than the iron that it originated from. Objects that have rusted tend to be larger than they were when they were a pure iron. This expansion can be dangerous. Pipes, if they burst, in large factories can cause thousands of dollars damage. Rust is weaker than pure iron. Rusted objects are unable to serve the purpose for which they were manufactured. Bridges, made from iron may rust. The bridge would not be as strong and would not support the weight of cars and so would collapse.
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Here is an example of some metals in the activity series:

- sodium
- magnesium
- aluminium
- zinc
- iron
- nickel
- lead
- copper
- silver
- platinum
- gold

The least reactive metals, such as gold, would be more appropriate for structures because they hardly corrode at all. These metals are also very expensive and inappropriate to build from.
The reactivity of a metal can be used for corrosion prevention.
When two metals are in contact with one another, the more reactive metal will corrode. The other metal will hardly corrode at all. This behaviour of the metals is used as a form of corrosion prevention.

Many ship hulls are made from iron. Because of the constant exposure to water the hull corrodes. Zinc is more reactive than iron and corrodes easily. If a block of zinc is attached to the iron hull the zinc will corrode. The iron, because of the presence of the zinc will not corrode. After all of the zinc has corroded, then the iron will begin to corrode. The zinc blocks need to be replaced regularly to ensure the iron hull will not corrode. The blocks of zinc used are a lot smaller than the large hull. It is a lot cheaper to constantly replace these zinc blocks than an entire ship's hull.

![Figure 5.2](image.png) The corrosion of zinc in preference to iron.
**Metal Coatings**

The corrosion of some metals is helpful rather than damaging. The surface of these metals undergo corrosion and form a metal oxide layer. Unlike other metals where corrosion continues from the initial site, the metal does not continue to corrode. The metal oxide layer remains stable and protects the metal underneath. No further corrosion can occur because oxygen and water cannot pass through the protective oxide layer.

Aluminium is a metal that forms an oxide layer. It is for this reason that aluminium is used for lightweight outdoor structures.

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Galvanising involves coating a metal with another metal. The metal that is used as a coating is one that forms its own protective oxide layer. When exposed to oxygen and air the surface of the coating metal chemically reacts and a protective oxide layer is formed. The oxide layer and the metal coating prevent exposure of the metal underneath to water and oxygen. Therefore the metal underneath does not corrode.

![Figure 5.3](image-url)  
*Figure 5.3 A microscopic picture of steel coated with zinc. (X 200)*
An example of galvanising is galvanised iron used for roofing. The iron is coated with a layer of zinc. Zinc is a metal that forms a oxide layer. Zinc is also higher than iron on the activity series. If the zinc oxide layer is scratched the zinc layer will corrode. The zinc layer acts in the same way that the zinc blocks do on the hull of a ship, and corrodes before the iron.
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Mixing small amounts of other metals has marked effects on the produced alloy's properties.

Alloys are created and used for different purposes. There are over 2000 different types of alloys. Each alloy has specific properties which are related to its use.

*Figure 5.4* The Rolls Royce radiator shell and famous 'silver lady'. Stainless steel is chosen for both because of its attractive appearance and corrosion resistance.
One of the properties that can be desirable in an alloy, is resistance to corrosion. Stainless steel is a good example of this. Stainless Steel is an alloy of chromium, nickel and steel. Steel is iron with a small amount of carbon added, the carbon increases the strength of the iron. Chromium and nickel are metals that do not corrode easily. The addition of the chromium and nickel greatly increase the resistance of the steel to corrosion.

The corrosion resistance of the steel alloy depends on the amount of chromium that is added. As more chromium is added the corrosion resistance increases. For example if the alloy contains 12-14% chromium then it usually used for kitchen utensils, so they remain shiny for decorative purposes. In very high quality car exhaust mufflers and in factories where high temperatures and dangerous chemicals are used the stainless steel contains 25-30% chromium. In these situations the corrosion resistance needs to be, and is, very high.
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CORROSION

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iron + oxygen + water ----> iron oxide (rust)
Once iron has began to rust it will continue to rust. This is because the initial piece of rust provides a site for the chemical reaction to continue occurring. Rust is also very porous and water and oxygen can pass through it to the iron underneath so that the process continues.

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- sodium (more reactive)
- magnesium
- aluminium (more easily corroded)
- zinc
- iron
- nickel
- lead
- copper
- silver (less reactive)
- platinum (less easily corroded)
- gold

The least reactive metals, such as gold, would be more appropriate for structures because they hardly corrode at all. These metals are also very expensive and inappropriate to build from.
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Figure 5.3 The structure of galvanised iron
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![Figure 5.4](image)

**Figure 5.4** The Rolls Royce radiator shell and famous 'silver lady'. Stainless steel is chosen for both because of its attractive appearance and corrosion resistance.
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![Diagram of steel coated with zinc](image)

**Figure 5.3** A microscopic picture of steel coated with zinc. (X 200)
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Alloys are created and used for different purposes. There are over 2000 different types of alloys. Each alloy has specific properties which are related to its use.

Figure 5.4 The Rolls Royce radiator shell and famous 'silver lady'. Stainless steel is chosen for both because of its attractive appearance and corrosion resistance.
One of the properties that can be desirable in an alloy, is resistance to corrosion. Stainless steel is a good example of this. Stainless Steel is an alloy of chromium, nickel and steel. Steel is iron with a small amount of carbon added. the carbon increases the strength of the iron. Chromium and nickel are metals that do not corrode easily. The addition of the chromium and nickel greatly increase the resistance of the steel to corrosion.

The corrosion resistance of the steel alloy depends on the amount of chromium that is added. As more chromium is added the corrosion resistance increases. For example if the alloy contains 12-14% chromium then it usually used for kitchen utensils, so they remain shiny for decorative purposes. In very high quality car exhaust mufflers and in factories where high temperatures and dangerous chemicals are used the stainless steel contains 25-30% chromium. In these situations the corrosion resistance needs to be. and is, very high.
Part 1  Introduction to corrosion.

1. Circle the correct response.
   A metal is more stable as
   (a) a pure metal
   (b) an oxide
   (c) a carbonate
   (d) a chloride

2. An owner of a car noticed a small spot of rust on the roof of his car.
   The owner left the spot thinking that it was just only a small amount.
   After a year the rust spot was a lot larger.
   Briefly explain the increase in size of the spot.

3. The legs of old fences made of iron are often embedded in concrete.
   Over time the iron rusts and the concrete cracks and chips away.
   Suggest a possible reason for the cracking and chipping of the concrete.
Part 2 Corrosion prevention

1. Circle the correct response.
   From the activity series, which of the following is the most reactive metal?
   (a) zinc
   (b) platinum
   (c) magnesium
   (d) copper

2. Inside the tanks of hot water systems there are rods of magnesium. The rods prevent the tank from corroding.
   Explain how the rods prevent corrosion of the tank.

3. Using the activity series, if aluminium and silver were in contact with each other, which metal would corrode first?
   Briefly explain why the chosen metal will corrode first.
Part 3 Metal Coatings

1. Circle the correct response.

The metal chosen to coat another metal is usually:

(a) lower on the activity series

(b) higher on the activity series

(c) in the same position on the activity series

(d) not on the activity series

2. A student performed an experiment where they scratched some aluminium with sand paper. Soon afterwards a white coating appeared on the surface. The teacher told the student that the coating was aluminium oxide. What is the purpose of this coating?

3. A plumber had to install a water tank. He had the choice between a zinc coated steel tank and a pure iron tank. The plumber chose the zinc coated tank because it would last longer. Explain why the zinc coating would extend the life of the tank.
Part 4 Alloys

1. Circle the correct response.
An alloy is:
(a) a metal that does not corrode
(b) a metal found near the sea
(c) a mixture of two or more metals
(d) a metal with special properties

2. Why does the addition of chromium to steel prevent corrosion of the steel?

3. What is the difference between an alloy and galvanising?
Appendix 6
MARKING KEY

Introduction to corrosion

2. 1 mark: mention of site, answer copied straight from text
2 marks: site for further reaction, mention oxygen and water, own words

3. 1 mark: expansion/rust
2 marks: expansion/rust, not clear, vague
3 marks: expansion or rust, no room, pushes out, clear definition, own words

Corrosion prevention

2. 1 mark: aluminium
2 marks: aluminium and reason

3. 1 mark: magnesium more reactive
2 marks: magnesium more reactive, will corrode first
3 marks: two metals in contact one corrodes first, magnesium because its more reactive

Metal coatings

2. 1 mark: protects metal prevents further corroding, answer copied straight from text
2 marks: stops water and oxygen contacting with metal therefore prevents further corrosion.

3. 1 mark: Oxide layer or zinc is more reactive (one reason)
2 marks: Oxide layer zinc more reactive (two reasons)
3 marks: Complete explanation, zinc more reactive and forms an oxide layer, will corrode first and forms the layer, twofold protection

Alloys

2. 1 mark: definition of one
2 marks: both definitions

3. 1 mark: chromium resistant to corrosion
2 marks: chromium increases the corrosion resistance because it is resistant to corrosion
3 marks: clear definition, because chromium is corrosion resistant this property also in metal therefore more corrosion resistant