Teaching for conceptual change and conceptual discrimination with year 8 science students: An exploratory study of the topic 'respiration'

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TEACHING FOR CONCEPTUAL CHANGE AND CONCEPTUAL DISCRIMINATION WITH YEAR 8 SCIENCE STUDENTS:
AN EXPLORATORY STUDY OF THE TOPIC 'RESPIRATION'

BY

S. Morgillo      B. Arts (Education)

A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.
Abstract

Research has shown that despite formal education, secondary and tertiary students hold a host of misconceptions about respiration.

This exploratory study investigated whether a four phase conceptual change teaching strategy could overcome conceptual problems typically associated with respiration, in a Year 8 science class from a school in Perth, Western Australia. The strategy consisted of a Conceptual Awareness Phase, an Exposition Phase, a Misconception Awareness Phase and an Application Phase.

Two-tier multiple choice test items used in previous studies to identify misconceptions about respiration were also used in this study, together with interviews. The encouraging results suggest that the implemented conceptual change strategy was successful in developing in Year 8 students an acceptable scientific conception of respiration, and an awareness that the term 'respiration' is used differently by the lay, medical and scientific communities. The strategy was also found to be successful in reducing the incidence of misconceptions typically associated with respiration.

Implications and recommendations for educators, textbook authors and curriculum writers, and the need for future research are discussed.
Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution 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 except where due reference is made in the text.

Signed

Date 20. 7. 93
Acknowledgements

A sincere thank you to Dr Mark Hackling, my supervisor, for his continual guidance, advice and invaluable feedback throughout this study.

Gratitude is also expressed to Dr David Tregust and to Dr Jerry Seymour for permission to use diagnostic test items from their studies.
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CHAPTER 1

INTRODUCTION

What Is Respiration?

To a scientist respiration is a series of chemical reactions releasing energy from food in cells (Bell, 1985). This food is synthesised by green plants using energy from sunlight by a process called photosynthesis (Keeton, 1980). Breathing is purely a mechanical process whereby air is drawn into and expelled from the lungs (Keeton, 1980). The relationships between respiration and photosynthesis are represented in Figure 1 below.

![Diagram of the relationship between respiration and photosynthesis]

Figure 1. Relationships between respiration and photosynthesis.
Problem

Research has shown that even though respiration is formally taught in school, the majority of secondary students do not understand it as either an oxidation of food process, or as an energy release process (Anderson, Sheldon & DuBay, 1986; Haslam & Treagust, 1987). Studies involving adults (Bishop, Roth & Anderson, 1986; Eisen & Stavy, 1988) and secondary students between the ages of 12-16 (Anderson et al, 1986; Haslam & Treagust, 1987; Seymour & Longden, 1991; Simpson & Arnold, 1982a) found that many students confused respiration and breathing, believing respiration was the exchange of gases between the organism and the environment. According to Seymour and Longden (1991) these conceptions result in a host of other related misconceptions pertaining to respiration.

Students who think of respiration as breathing are generally unaware that food plays any role in respiration, have little appreciation of the function of respiration and hold the naive conception that animals "breathe in" oxygen whereas plants "breathe in" carbon dioxide (Bishop et al., 1986). Most secondary students lack the understanding that respiration in plants is an ongoing process in both light and dark conditions (Barrass, 1984; Treagust, 1988). Clearly, secondary students do not comprehend the nature of respiration, and they have little comprehension of the relationship between photosynthesis and respiration in plants (Haslam & Treagust, 1987).
Significance

The processes of respiration and photosynthesis are basic to an understanding of the functioning of biological and ecological systems (Anderson et al., 1986; Bishop et al., 1986) and to an understanding of the mutual relationships between organisms in an ecosystem, which is one of the main goals of biological education (Eisen & Stavy, 1988).

Students come to lessons with preconceived ideas about respiration which, although these appear sensible to the learner, are often in marked contrast with scientific conceptions (Hashweh, 1986; Hewson & Thorley, 1989; Simpson & Arnold, 1982a). Students use these alternative frameworks to make sense of classroom instruction. Consequently, many students retain misconceptions about respiration throughout secondary school and their understanding of respiration and photosynthesis have remained fundamentally disjointed, incoherent, and partially erroneous, as they hold both intuitive and scientific ideas concurrently (Anderson et al., 1986; Bell, 1985; Bishop et al., 1986; Haslam & Treagust, 1987).

Although several studies have identified misconceptions about respiration, there appears to have been little research on altering students' conceptions of this process. It is envisaged that this study will be particularly significant to educators and curriculum
writers committed to minimising misconceptions about respiration and associated topics.

Purpose and Research Questions

The purpose of this investigation was to develop and evaluate an instructional strategy to help Year 8 students develop an adequate scientific conception of respiration, and to discriminate between its scientific and everyday meanings.

More specifically, to what extent can a teaching strategy based on conceptual change models:

1. develop in Year 8 students an acceptable scientific conception of respiration;
2. alleviate the misconception that respiration is synonymous with breathing;
3. develop an awareness in Year 8 students that the term 'respiration' is often interpreted and used differently by the lay, medical and scientific communities;
4. reduce the incidence of misconceptions relating to respiration and photosynthesis in plants, which the literature has associated with traditional instruction; and
5. enhance students' understanding of key concepts within the topics of respiration and gaseous exchange, which the literature suggests is poorly understood as a result of traditional instruction.
Research Questions 1, 2 and 3 were concerned predominantly with the strategy’s capability to develop students’ understanding of respiration and to reduce the frequency of misconceptions associated with that topic. Research Questions 4 and 5 were concerned with the effectiveness of the instructional approach compared with previous findings based on traditional instruction.
CHAPTER 2

LITERATURE REVIEW

How Conceptions Form

Concepts are objects, events, situations or properties that possess common criterial attributes and are designated in any given culture by some accepted sign or symbol (Ausubel, Novak & Hanesian, 1978). Formal science learning can be viewed as involving a shift from one set of beliefs about the physical world to another, by generating new conceptions from the prior ones and from experiences (Osborne & Wittrock, 1985). Constructivism provides a powerful perspective for understanding, interpreting and influencing student learning of scientific concepts (Hewson & Hewson, 1988; Hewson & Thorley, 1989; Nussbaum, 1989).

Constructivism advocates that both the teacher and curriculum activities help the students to actively construct their own meaning from instructional material (Driver, 1989; Nussbaum, 1989). Instructional strategies based on constructivist ideas have been successful in obtaining significant changes in the alternative conceptions held by students (Hameed, Hackling & Garnett, 1993; Hewson & Hewson, 1988).

A major influence on constructivist tradition has been Piaget who contended that all knowledge is constructed by the individual as he or she interacts with the environment
and tries to make sense of it; and knowledge is acquired not by the internalisation of some outside given meaning but by construction from within, of appropriate representations and interpretations (Driver, 1989; Maggoon in Osborne & Wittrock, 1985).

The term 'accommodation' has been adopted from Piaget's theory to denote what happens as a student modifies his or her preconception to reach consonance with the accepted scientific conception (Nussbaum & Novick, 1982). The word 'assimilation' has been used to refer to learning where a major conceptual revision is not required.

Consistent with Piagetian and Ausubelian theories, which both emphasise the active role of the learner in constructing meaning, Osborne and Wittrock's Generative Learning Model (GLM) explains how students' pre-existing alternative frameworks (also called preconceptions) interact with new knowledge during instruction to generate misconceptions.

Osborne and Wittrock (1985) postulate that the learner's existing ideas influence what aspects of sensory input are attended to and the learner generates links between the selected aspects of sensory input and existing conceptions retrieved from long term memory to actively construct meaning. These constructed meanings may be tested against other aspects of memory store and the learner may subsume these constructions into long term
memory (Osborne & Wittrock, 1985). The main features of the GLM model are illustrated in Figure 2, below.

![Diagram of the Generative Learning Model (GLM)](image)

**Figure 2.** The Generative Learning Model (Osborne & Wittrock, 1985).

The construction of a misconception begins with a knowledge 'gap', determined by previous knowledge and experiences. Construction proceeds as potentially gap-filling sensory input is selected and modified (Rowell, Dawson & Lyndon, 1990). The resulting knowledge, the misconception, is the 'best' the learner is able to produce at that point in time and will be the basis for future learning, regardless of its limitations (Hashweh, 1986; Rowell et al., 1990; Strike & Posner, 1985).

Many classroom activities and assessment procedures do not encourage students to generate appropriate links between sensory input and existing knowledge, or to construct meaning and critically evaluate this meaning against other aspects of existing knowledge (Osborne & Wittrock, 1985). Students' self-centred points of view,
limited experiences and everyday use of language ensure that students develop ideas which are different from those of scientists (Osborne & Wittrock, 1985).

Persistence of Alternative Frameworks

It is commonly agreed that preconceptions are amazingly tenacious and resistant to extinction (Cosgrove & Osborne, 1985; Hashweh, 1986; Hewson & Thorley, 1989; Kuhn, 1989; Posner, Strike, Hewson & Gertzog, 1982; Rowell et al., 1990). Misconceptions typically outlive teaching which contradicts them (Viennot, cited in Posner et al., 1982), and act as critical barriers to learning despite formal instruction (Bishop et al., 1986; Nussbaum & Novick, 1982).

An existing schema will not necessarily be changed simply by presenting a new set of propositions (Nussbaum & Novick, 1982). Even in the face of contradictory evidence where an experimental test invalidates all but one view, or where a student is dissatisfied with his or her current explanations of phenomena, some students will simply refuse the counter evidence (Cosgrove & Osborne, 1985; Osborne & Wittrock, 1985; Strike & Posner, 1985). Others will render the anomaly as a special case or as an exception to the rule (Strike & Posner, 1985). Some students will reject new information as they find the changes strenuous and potentially threatening to firmly committed assumptions (Osborne & Wittrock, 1985; Posner et al., 1982; Strike & Posner, 1985). Lack of objectivity and metacognitive
awareness are also responsible for students' rejection of evidence that is inconsistent with their own beliefs (Kuhn, 1989).

It has been suggested by Hashweh (1986) that traditional common sense explanations reinforce alternative frameworks, influencing their persistence. Many students pass courses with good grades yet retain their preconceptions because evaluation methods often fail to reveal alternative frameworks (Hashweh, 1986; Nussbaum & Novick, 1982). Even when revealed by students' answers, preconceptions are not addressed as the teacher often fails to recognise their significance (Hashweh, 1986; Strike & Posner, 1985).

Origin of Respiration Misconceptions

Prior to formal instruction students encounter the word 'respiration' in everyday use, reinforcing the misconception that it is synonymous with breathing (Barrass, 1984; Seymour & Longden, 1991).

Although Anderson et al. (1986, p. 9) claim that "we have never seen a biological text that defines respiration in its common-language sense", the problem of everyday language usage is exacerbated by human biology textbooks which define respiration as a process taking place in the lungs, in which oxygen is absorbed into the blood and carbon dioxide is released into the air (Bishop et al., 1986). These textbooks also typically use terms such as
respiratory system, internal respiration, external respiration, respiratory surface, tissue respiration, cellular respiration and respiratory pigment, which are misleading and should be discarded as they are not necessary, and contribute to students confusing the process of respiration with that of breathing and/or gaseous exchange (Barrass, 1984). Teachers and students generally believe what they read from texts and expect science textbooks to be scientifically accurate (Barrass, 1984).

Difficulties with respiration, however, can not be totally attributed to common usage of the term as photosynthesis, unlike respiration, has no non-biological meaning yet many misconceptions are associated with this process (Anderson et al., 1986).

According to Anderson et al. (1986), Bishop et al. (1986) and Watts (cited in Bell, 1985) difficulties may be due, not so much to the abstractness of the concept itself, but to the alternative concepts held by students of the more basic concepts such as food, living, energy and gases, which are essential to make sense of respiration and photosynthesis (Bell 1985; Bishop et al., 1986; Hashweh, 1986).

Eisen and Stavy (1988) contend that secondary science curricula all over the world were developed without considering students' difficulties in understanding essential related concepts. According to Hashweh (1986)
this is probably the area that is most neglected by researchers interested in conceptual change in science.

Research by Anderson et al. (1986), which showed that the amount of biology studied in secondary schools had no apparent effect on students' misconceptions, suggests that children's alternative conceptions of respiration have not been adequately addressed by teachers or curriculum designers.

Some teachers do not understand the scientific conception of respiration and their choice of some demonstrations reinforces the misconception that respiration occurs continuously in animals, but only during the night in plants (Barrass, 1984). Furthermore, equations where photosynthesis and respiration are presented as 'opposites' by teachers can cause students to think that photosynthesis and respiration could not occur simultaneously (Barrass, 1984).

Conceptual Change

Strike and Posner (1985) state that accommodation can be viewed as a competition between conceptions. Whenever the alternative's status exceeds the existing conception's status, accommodation will move forward. Competition between conceptions results in a process of accommodation characterised by temporary advances, frequent retreats, and periods of indecision. Accommodation involves much fumbling about and many false starts and mistakes (Hewson &
Hewson, 1988). Studies suggest that conceptual change forms an evolutionary pattern in which the student maintains substantial elements of the old conception while gradually incorporating individual elements from the new one (Kuhn, 1989; Nussbaum, 1989). Although accommodation is a radical change, it is not necessarily abrupt, and for many students, will be a gradual and piecemeal affair (Kuhn, 1989; Strike & Posner, 1985).

Science teachers should be convinced of the need to use instructional strategies that take into account students' existing conceptions, especially when they conflict with those being taught (Bishop et al., 1986; Hewson & Hewson, 1988; Kuhn, 1989; Seymour & Longden, 1991). More specifically these include strategies which diagnose students' conceptions, allow students to clarify their ideas, allow the teacher to present the scientific conception, establish a direct contrast between different views, and allow opportunities for explanation of and application to a range of examples (Hewson & Hewson, 1988).

Conditions for Conceptual Change

If students are to accept scientists' interpretations of phenomena, they have to change their minds in ways which may require restructuring of their existing conceptions, rather than simply adding new knowledge. Teachers therefore need to be aware of students' entering knowledge, and plan their instruction to take account of this (Cosgrove & Osborne, 1985; Hewson & Hewson, 1988).
Thinking about learning in this way led to the development of a conceptual change model (CCM) by Posner et al. (1982) who drew on the philosophy of science and the works of Kuhn (1970), Lakatos (1970) and Toulmin (1972) in particular. According to the CCM of Posner et al., students resist making changes unless they are dissatisfied with their current concepts and find an intelligible and plausible alternative that appears fruitful for further inquiry (Posner et al., 1982).

The model proposed by Posner et al. has been elaborated on by Hewson and Thorley (1989) who state that the extent to which a new conception meets these three conditions determines the status of a person's conception. Expressed in these terms, a fourth condition in the CCM is the raising or lowering of the conception's status.

Posner et al. (1982) state that there must be dissatisfaction with the existing concept before the learner will seriously consider a new one. One major source of dissatisfaction is the anomaly, which exists when one cannot make sense of something that is presumed assimilable. The more students consider the anomaly to be serious, the more dissatisfied they will be with current concepts, and the more likely they may be to accommodate new ones.

Minimal understanding of a concept is a necessary first step in raising status. Without intelligibility, a conception has no status and cannot become plausible or
If dissatisfaction with an existing concept is followed by learning of an intelligible alternative which appears to resolve the anomalies of its predecessor, the new conception may be plausible (Posner et al., 1982). Accommodation involves both understanding and acceptance (Strike & Posner, 1985).

A conception that resolves its predecessor's anomalies and leads to new insights and discoveries, will appear fruitful to the extent that students can generate or understand novel practical applications from it (Hewson & Thorley, 1989).

Providing opportunities for the desired view to be used in explaining a phenomenon will render it plausible, and the application of the new interpretation to different examples will show it to be fruitful (Hewson & Hewson, 1988).

Instructional Models for Conceptual Change

Rowell, Dawson and Lyndon's Old Way/New Way Technique

Research by Rowell et al. (1990) found that teaching a better theory followed by co-operative debate was successful only for some students, whereas a better theory followed by an old way/new way strategy produced better
results in bringing about conceptual change. This alternative old way/new way technique, based on Piagetian equilibration strategies for changing misconceptions, requires teachers to point out the similarity and differences between student and scientific conceptions of a phenomena. Students are directed to produce the old and new way and state their differences five times, and then to use the correct interpretation six times in context with the topic. These numbers of repetitions, spaced over a period of about two weeks, have been empirically established as necessary. The essence of this procedure is that the reactivation of errors is necessary for their illumination and that the labelling of competing knowledge for systematic discrimination, and the generalisation of the new way are all needed for error replacement (Rowell et al., 1990).

The old way/new way sequence directs attention to the competing possibilities, providing greater instructional control than co-operative debate as it directs debate (Rowell et al., 1990). When students raise a problem it is examined in terms of a framework of "old" and "new" possibilities.

To be an effective competitor the new theory must be understood and believable. For co-operative debate to be possible, both theories must be unambiguous, identifiable and discriminable by individuals, because the essence of debate is the juxtaposition of arguments, followed by
rational conviction and elimination (or restriction) of the defeated idea (Rowell et al., 1990).

Rowell et al.'s technique is supported by Seymour and Longden (1991) who suggest that teachers should highlight the distinction between the everyday and the scientific use of the term 'respiration', and encourage students to use the terms 'breathing' and 'respiration' in a scientifically acceptable manner.

\textit{Cosgrove and Osborne's Four Phase Model}

Cosgrove and Osborne's (1985) four phase model has three specific objectives: clarification of pupils' existing views, modification of these views towards the current scientific view, and consolidation of the scientific view within the background experience and values of the pupils.

The four phase model has an explicit teacher preparation phase and three teaching phases. During the Preliminary Phase teachers should ascertain from the literature the potential range of alternative frameworks that may be possessed by the students and develop scientifically accepted explanations of the phenomenon. The aim of the Focus Phase is to provide a context for later work and to make explicit students' existing conceptions. During the Challenge Phase students can present their own views to a group where differences can be displayed and discussed. Where appropriate, the teacher
should introduce the scientists' views at a level suitable for the students. If possible students should devise experimental tests of the alternative explanations (Cosgrove & Osborne, 1985).

The Application Phase assists students to clarify and consolidate the new view through its application in a range of new contexts. The teacher's role in this phase is to actively diagnose pupils' existing ideas, encourage them to try alternative solutions, challenge pupils to think about phenomena in terms of the new viewpoint and encourage a reflective thinking approach (Cosgrove & Osborne, 1985).

Conceptual Change Versus Conception Discrimination

Hashweh's Model

Hashweh (1986) questions the validity of some studies of conceptual change brought about by cognitive conflict dialective process, and presents a model of conceptual change which considers factors affecting persistence of preconceptions, the acquisition of new conceptions and cognitive restructuring. Figure 3 (overleaf) represents what Hashweh proposes might be involved in conceptual change.
According to this model a preconception is usually successful in interacting with a particular domain of the world R1 but fails to interpret a second portion of the world R2, bringing about cognitive conflict. It has traditionally been assumed that conflict 1 is resolved by adopting concept 2 which better explains R2. However, adopting concept 2, according to Hashweh (1986), does not resolve conflict 1. Both types of conflicts have to be resolved for restructuring to occur. The two conflicts can be resolved by a process of demarcation; showing the "domain of explanation" of each or indicating the part of the world to which each concept can be successfully mapped. Conflict 2 is resolved by showing that concept 1 is successfully related to R1 but not to R2; and by showing that conception 2 represents R2 as well as R3 (Hashweh, 1986).
These types of explanations, which show students that their preconceptions are not wrong but limited, are further supported by Solomon (1983). Children's non-scientific understandings of science conceptions through the use of everyday language and experience, can not be easily extinguished (Solomon, 1983). School learning has less social currency as it is restricted to a small group of technical people (Kuhn, 1989; Schutz & Luckmann in Solomon, 1983). Students, in Solomon's (1983) view, must never lose the ability to communicate with society at large, and she advocates that students "should be able to think and operate in two different domains of knowledge and be capable of distinguishing between them." (p. 50).

Relevant information from this chapter, together with the key aspects of Posner et al.'s model, Rowell et al.'s technique, Cosgrove and Osborne's model and Hashweh's model have been drawn together to design the four phase conceptual change teaching strategy aimed at developing in students a scientific conception of respiration, while still appreciating its lay and medical meanings. The development of this conceptual change strategy is discussed in the following chapter.
CHAPTER 3

METHODOLOGY

Design of Study

The purpose of this study was to gather preliminary data to establish whether a teaching strategy based on conceptual change models could enhance students' understanding of the term 'respiration' and reduce the incidence of misconceptions typically associated with this process.

To address the five research questions a treatment group was exposed to a conceptual change teaching strategy, and some of the quantitative data were compared to previous research findings involving traditional instruction. Both quantitative and qualitative data were used to answer the research questions. Figure 4 below, gives an outline of the design of the study.

KEY
X(A): Conceptual change teaching strategy.
X(B): Past research on students' understanding and misconceptions of respiration, where traditional instruction had been used.
T : Pencil and paper test of whole class/classes.
I : Interview a sample of six students.

Experimental Group: T I X(A) T I

Past Research: X(B) T

Figure 4. Design of the study.
Subjects

The subjects were the current Year 8 students taught by the writer. The group consisted of 28 girls and boys of mixed ability, from a low to medium socio-economic background. It was the first time that these students had received formal instruction on respiration at secondary school.

Instruments

To enhance the validity of this study two data collection methods were used; interviews and pencil and paper tests. Interviews were conducted to collect in-depth information from students about their conceptions of respiration. Three male and three female students were selected on the basis of some demonstrated weaknesses in the pretest, a strategy used by Seymour and Longden (1991). Permission to conduct and record the interviews was sought from the students themselves, and they were informed about the purpose of the interviews.

A pencil and paper test was administered before instruction (pretest), after instruction (posttest), and again four weeks after instruction (delayed posttest) to determine whether the conceptions were firmly established in the students' minds. The test was constructed using one open-ended question, and 16 two-tier multiple choice items selected from Haslam and Treagust's (1987) study and Seymour and Longden's (1991) study.
Nine of the test items deemed appropriate for this study were selected from Haslam and Treagust's test. Haslam and Treagust used their test in Western Australian schools to diagnose 441 Year 8-12 students' understanding of respiration and photosynthesis in plants. It involved five pilot studies and had a reliability (using Cronbach's coefficient alpha) of 0.72, and a readability range between Years 7-8 using Fry's Readability Graph.

Seymour and Longden used a two-tier multiple choice test similar to Haslam and Treagust's to establish the difficulties an English sample of 148 Year 9 and Year 11 science students had in understanding respiration and gaseous exchange. Seven items were selected from this test which was also developed from pilot studies. The reliability, determined by employing a split half reliability technique, produced a coefficient of 0.88 and the readability level matched the sample.

The design of these test items involved a first tier multiple choice content question related to a number of propositional statements. The second tier consisted of a multiple choice set of reasons for the answer selected in the first tier. Both tests offered scientific and non-scientific distractors, and gave students the option to include a reason other than those provided. The distractors were based on students' responses to interviews, open ended questions and/or past research. The test items selected for this study (presented in Appendix A), were used to identify which aspects of
respiration students understood and the misconceptions they held.

Data Analysis

Students were required to select the appropriate first and second tier distractors to record a correct response in the multiple choice test items. Changes in students' interview responses following instruction were summarised and tabulated.

Research Question 1 was addressed by:

1. comparing students' pretest, posttest and delayed posttest mean scores gained on the pencil and paper test, where a two-tailed t-test for paired data was used, level of significance been p < 0.01; and

2. using specific test items and interview responses to establish the extent to which students could

(a) define respiration as a process where food and oxygen combine to release energy, water and carbon dioxide,

(b) state that it occurs in all cells, and

(c) state that it is an ongoing process.

The findings in relation to students' understanding, and misconceptions of these key aspects of respiration were examined before and after instruction, and the pencil and paper test results were compared with those reported in other studies. The extent to which Research Questions 2, 3, 4 and 5 were answered also impinged on Research Question 1.
Research Question 2 was answered using the appropriate pencil and paper test item, as well as the interview responses.

Interview responses and classroom observations were used to address Research Question 3.

Research Questions 4 and 5 were addressed by comparing the posttest results of this study with the posttest results reported by Haslam and Treagust, and Seymour and Longden respectively, using identical test items.

Figure 5 below summarizes the instruments used to address the relevant research questions.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Pencil &amp; paper</th>
<th>Personal two-tier tests</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>No. 3</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 5</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Instruments used to address the five research questions.

Convergent validity of the two data sources was established by comparing the six interviewed students' test results with their interview responses, focusing on four key misconception areas which were found to be prevalent in this and other studies.
Limitations

It is acknowledged that ideally the subjects should have been a random sample. However, the use of intact classes in this study reduced disruption to students' and the school's program, enabling routine treatments and tests to be implemented. This, according to Isaac and Michael (1983), also enhances the external validity of the study as it reduces the chance of students being aware that they are involved in experimental research.

The size of the experimental group was small (n=28), and the range of students' abilities may not have been representative of the general Year 8 population.

Although internal validity can be enhanced with the use of a control group to ensure against extraneous factors such as previous exposure to the testing instruments and/or interviews (Borg & Gall, 1989; Isaac & Michael, 1983), the use of a control group may have introduced a number of other limitations. For example, to what extent would the control and experimental groups have been equivalent and, more importantly, to what extent could the control group have represented traditional instruction, particularly as the teacher of the control group would have been aware that his or her teaching strategies, were to be compared with a proposed 'better' strategy.

It is further acknowledged that the number of students, their educational background, instructional
duration on respiration, the time between instruction and the posttest, as well as the place and time of testing, in both Haslam and Treagust's, and Seymour and Longden's research, did not match the experimental group's. These past studies, however, used reliable and valid instruments on secondary students to identify misconceptions, and poorly understood aspects of respiration evident after instruction, and these instruments were used for the same purpose in this study. Consequently, it is suggested that where comparisons needed to be made with traditional instruction, it was more appropriate to compare the experimental group's results with past research findings where traditional instruction was used, than with a current control group which was likely to be atypical.

Several comparisons were made where the mean frequencies obtained in this study were compared with those from past research findings. However, it is acknowledged that comparisons based only on a single test item may not be reliable.

External validity with regards to Research Questions 1 and 2, however, was enhanced by the use of both qualitative (interviews) and quantitative (pencil and paper tests) instruments providing triangulation of data sources (Isaac & Michael, 1983; Jick, 1979). The convergent validity of these data sources was determined by comparing the level of agreement between students' responses to these two instruments.
Preliminary Questionnaire

At the beginning of the school year an informal questionnaire was administered to all Year 8 students at the writer's current school. The majority of students claimed that they were not aware of what respiration meant, and of those who gave a definition, nearly all confused respiration with breathing. None of the students appeared to hold a scientific conception of respiration.

Conceptual Change Instructional Strategy

The conceptual change instructional strategy used in this study was based on constructivist philosophy, relevant literature and on a selection of ideas from a number of conceptual change models.

Although the implemented strategy has similar objectives to those of Cosgrove and Osborne's (1985) model of teaching for conceptual change, it differs in that it aims to develop in students a scientific conception of respiration as well as an awareness of its lay and medical meaning. To give students every opportunity possible to achieve this goal, several ideas from a range of conceptual change models were adopted and incorporated in the conceptual change teaching strategy. The conceptual change models drawn on included:

1. Posner et al.'s model which emphasises that a new idea should be intelligible, fruitful and plausible and that it should have a higher status than existing ideas;
2. Rowell et al.'s old way/new way technique which stresses the importance of making explicit the similarities and differences between student and scientific conceptions;  
3. Cosgrove and Osborne's model which emphasises the need to use students' existing knowledge to consolidate the scientific viewpoint; and  
4. Hashweh's model which proposes that students should be shown how differently held conceptions relate to various parts of the real world.

The conceptual change teaching strategy was implemented for a duration of 480 minutes over two weeks and consisted of the following four phases.

1. A Conceptual Awareness Phase. During this phase students were required to clarify their meaning of respiration and compare it to those of others (a strategy supported by Cosgrove & Osborne, 1985). To influence students' attention to the topic and motivate them to establish the 'correct' meaning of respiration, students were required to:
   (a) interview a number of adult lay persons, medical professionals and those with a biological background; and  
   (b) conduct a definition search, where definitions of breathing and respiration were obtained from a variety of sources including English dictionaries, biology textbooks, human biology textbooks, standard lower school science textbooks and science encyclopedia.
Students were then required to tabulate, compare and contrast the results of the interviews and definition search, and compare their findings with those of their peers to form generalisations. As stated by Yager (1991) accommodation can be enhanced by encouraging students to elaborate and challenge each other's conceptualisation, while providing time for reflection and collection of ideas.

It was anticipated that the above strategies would have helped students to accept that the term 'respiration' is used and interpreted differently. Consequently, students should not have been threatened by the scientist's interpretation, and resistance to changes in their own preconceptions should have been minimised. The opportunity was provided for students to discover for themselves that the scientific interpretations of breathing and respiration are consistent and reliable and they do not require clarification as is the case with other interpretations.

At the completion of this phase students' findings were clarified by the teacher who emphasised the different interpretations of respiration held by various segments of the community. Students' entering knowledge was established, which is essential if firm links between new and existing ideas are to be generated (Posner et al., 1982; Yager, 1991). As supported by Osborne and Wittrock (1985) at this stage of the instructional intervention it was important to explicitly state the purpose and significance of the current and subsequent instruction.
2. Exposition Phase. Instruction during this phase, with the aid of specifically written materials, reinforced the range of meanings associated with respiration, and addressed essential related concepts. These included living, breathing, gaseous exchange, food, energy, photosynthesis, energy transformation and the relationship between respiration and photosynthesis.

Conceptual change strategies have been found to be strongest when teachers had developed their own teaching materials (Anderson et al., 1986; Hewson & Hewson, 1988). The teacher's own written materials used in this study had carefully worded headings ensuring related topics were appropriately covered and linked to the process of respiration. In addition, the materials explicitly compared and contrasted scientific interpretations with commonly held student views. This, according to Cosgrove and Osborne (1985), Osborne and Wittrock (1985) and Bishop et al. (1986) can help minimise student misconceptions.

3. A Misconception Awareness Phase. As stated by Posner et al. (1982) a conceptual change will be rational to the extent that students have at their disposal the requisite standards of judgment necessary for change. The results obtained from the Conceptual Awareness Phase exposed students to commonly held misconceptions relating to respiration. These misconceptions and their possible origin were subsequently explicitly addressed during this phase of instruction.
4. An Application Phase. In keeping with Cosgrove and Osborne (1985) and Karplus (1980) the Application Phase required students to apply their knowledge and solve problems using their newly acquired scientific viewpoint. These strategies according to Posner et al. (1982), Osborne and Wittrock (1985) and Bishop et al. (1986) help to show students that the scientists' meaning works better than their original misconception.

A set of problems given to the students was designed by Bishop et al. (1986) specifically to:

1. encourage student thinking about the process of respiration and energy conversion using everyday experiences such as dieting and weight loss;
2. confront the conception that respiration is breathing;
3. reinforce the reactants and products of respiration, and where this process occurs; and
4. reinforce the relationship between respiration and photosynthesis.

In keeping with a range of key ideas from Hashweh (1986), Solomon (1983) and Rowell et al. (1990), students were also required to use the terms 'respiration', 'breathing' and 'energy' in a lay, medical and scientific context with regards to plants and animals.
CHAPTER 4

RESULTS

Introduction

A pencil and paper test comprising 16 two-tier multiple choice items and an open ended question, with the support of personal interviews was used to establish students' understanding, and the frequency of misconceptions about respiration, gaseous exchange and the relationship between respiration and photosynthesis, before and after instruction. The data were then used to compare the findings of this (Morgillo's) study with those where traditional teaching methods have been used. Interviews were also used to determine whether the conceptual change teaching strategy was successful in developing students' awareness that the term 'respiration' is used and interpreted differently by lay, medical and scientific persons.

Students' Understanding of Respiration, Gaseous Exchange and the Relationship Between Respiration and Photosynthesis

Table 1 presents students' (n=28) pretest, posttest and delayed posttest mean scores on the 17 item pencil and paper test. The items in the test assessed the extent to which students developed an acceptable scientific conception of respiration, gaseous exchange, and the relationship between respiration and photosynthesis.
TABLE 1
Students' Mean Scores and Standard Deviation on the Pencil and Paper Pretest, Posttest and Delayed Posttest

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard deviation</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>3.82</td>
<td>1.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>10.50</td>
<td>3.68</td>
<td>10.82</td>
<td>*</td>
</tr>
<tr>
<td>Delayed posttest</td>
<td>10.25</td>
<td>3.91</td>
<td>9.84</td>
<td>*</td>
</tr>
</tbody>
</table>

*p < 0.01 for a two-tailed t-test for paired data

Out of a possible score of 17, the mean test score was 3.82 on the pretest, 10.50 on the posttest, and 10.25 on the delayed posttest which was administered four weeks after the posttest. The difference between the pretest and posttest means, and between the pretest and delayed posttest means were significant at the p < 0.01 level.

Students' Understanding of Respiration and Gaseous Exchange Compared with Previous Studies

Seven multiple choice items used in this study were taken from Seymour and Longden's (1991) study which found that students performed poorly on six of these test items following traditional instruction. Table 2 compares the percentages of correct responses, relating to students' understanding of respiration and gaseous exchange, obtained by the Year 8 students (n=28) in Morgillo's study with a sample of Year 9 (n=60) students who had not been taught respiration and a Year 11 (n=77) sample who received traditional instruction on respiration.
TABLE 2

Students' Understanding of 'Difficult' Respiration and Gaseous Exchange Concepts, Following Traditional Instruction (Seymour & Longden, 1991) and Teaching for Conceptual Change (Morgillo, 1993)

<table>
<thead>
<tr>
<th>Test item</th>
<th>Content addressed in question</th>
<th>Before Instruction</th>
<th>After Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Respiration occurs in cells.</td>
<td>41.7</td>
<td>51.9</td>
</tr>
<tr>
<td>6</td>
<td>Oxygen is used in respiration which occurs all the time in plants.</td>
<td>18.3</td>
<td>31.2</td>
</tr>
<tr>
<td>8</td>
<td>Food is a source of energy for respiration.</td>
<td>26.7</td>
<td>26.0</td>
</tr>
<tr>
<td>10</td>
<td>Respiration is the oxidation of food.</td>
<td>6.7</td>
<td>37.7</td>
</tr>
<tr>
<td>4</td>
<td>Blood carries oxygen from the lungs to the cells. and carbon dioxide from the cells to the lungs.</td>
<td>15.0</td>
<td>41.6</td>
</tr>
<tr>
<td>1</td>
<td>Exhaled air contains carbon dioxide, nitrogen and oxygen.</td>
<td>16.7</td>
<td>40.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Correct Responses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Instruction</td>
<td>After Instruction</td>
</tr>
<tr>
<td></td>
<td>Seymour and Longden (n=60)</td>
<td>Morgan (n=77)</td>
</tr>
<tr>
<td></td>
<td>Year 9</td>
<td>Year 11</td>
</tr>
<tr>
<td></td>
<td>Year 8</td>
<td>Year 8</td>
</tr>
</tbody>
</table>

Note: * Seymour and Longden's figures are from Seymour (1989, p. 88).

Table 2 shows that Seymour and Longden's Year 9 students have a mean percentage of 19.2% which is similar to the 16.7% achieved by the experimental group. Bearing in mind that the same test items were used, it can be postulated that the experimental group and Seymour and Longden's Year 9 sample had similar entering knowledge. After teaching for conceptual change the Year 8 experimental group had a higher frequency of correct responses than Seymour and Longden's Year 11 group in five of the six areas addressed. In addition the experimental group achieved a mean score of 53.6%, compared with 38.1% achieved by Seymour and Longden's Year 11 sample.
Student Misconceptions

Table 3 presents the pretest, posttest, and delayed posttest frequencies of misconceptions revealed by the 17 item pencil and paper test. Only those misconceptions held by more than three students (10.71%) on the pretest have been tabulated.

TABLE 3
Frequency of Misconceptions Held by Year 8 Students (n=28) on the Pretest, Posttest and Delayed Posttest

<table>
<thead>
<tr>
<th>Number</th>
<th>Misconception</th>
<th>Pre test</th>
<th>Post test</th>
<th>Delayed posttest</th>
</tr>
</thead>
</table>
| 1      | Gaseous exchange

1. During breathing all of the oxygen is absorbed and is replaced by carbon dioxide. Nitrogen in the air is unaffected.  
17.86 10.71 7.14

2. During breathing all of the oxygen and all of the nitrogen is absorbed. Carbon dioxide only is breathed out.  
17.86 3.57 0.00

3. The blood does not carry gases.  
17.86 3.57 0.00

4. The blood carries only oxygen.  
32.14 28.57 25.00

5. Respiration is synonymous with breathing.  
42.86 3.57 7.14

6. Respiration is synonymous with sweating.  
21.34 0.00 0.00

7. Respiration in green plants is the taking in of carbon dioxide and giving off of oxygen gas through plant's stomates.  
14.29 3.57 0.00

8. Reactants and products of respiration

8. Carbon dioxide is used in respiration.  
25.00 14.29 3.57

9. Green plants stop photosynthesising when there is no light energy so they continue to respire and give off oxygen.  
21.43 25.00 10.71

10. Respiration and energy

10. Not all living things (animals and plants) need to respire.  
21.43 7.14 3.57

11. Plants get energy from photosynthesis.  
28.57 0.00 3.57

12. Energy acquired via respiration is extracted from oxygen.  
28.57 3.57 3.57

13. Oxygen can be used as a source of energy for respiration.  
28.57 14.29 10.71

14. Carbon dioxide can be used as a source of energy for respiration.  
14.29 10.71 7.14

15. Where respiration occurs

15. Respiration occurs only in the lungs (where energy is released).  
35.71 3.57 3.57

16. Respiration occurs only in the stomach (where energy is released).  
21.43 3.57 14.29

17. Respiration in plants takes place in the cells of leaves only.  
14.29 14.29 14.29
<table>
<thead>
<tr>
<th>When respiration occurs</th>
<th>18 Respiration in green plants takes place only during the day.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35.71 10.71 10.71</td>
</tr>
<tr>
<td></td>
<td>19 Respiration in green plants does not take place in the presence of light energy.</td>
</tr>
<tr>
<td></td>
<td>28.57 10.71 21.43</td>
</tr>
<tr>
<td></td>
<td>20 Green plants respire only when there is no light energy.</td>
</tr>
<tr>
<td></td>
<td>14.29  7.14  0.00</td>
</tr>
<tr>
<td></td>
<td>21 Green plants respire only at night (when there is no light energy).</td>
</tr>
<tr>
<td></td>
<td>21.43  7.14  14.29</td>
</tr>
<tr>
<td></td>
<td>22 Carbon dioxide is used in respiration which occurs in green plants when there is no light energy to photosynthesize.</td>
</tr>
<tr>
<td></td>
<td>14.29  0.00  7.14</td>
</tr>
</tbody>
</table>

| When photosynthesis occurs                      | 23 Photosynthesis only occurs at night.                        |
|                                                 | 25.00 3.57  7.14                                            |
|                                                 | 24 Photosynthesis occurs in plants when there is no light energy. |
|                                                 | 25.00 17.86 14.29                                           |
|                                                 | 25 Oxygen is given off by green plants during photosynthesis which takes place when there is no light energy. |
|                                                 | 21.43  7.14  17.86                                         |
|                                                 | 26 Carbon dioxide is given off by green plants during photosynthesis which takes place when there is no light energy. |
|                                                 | 25.00  3.57  17.86                                         |
|                                                 | 27 Photosynthesis occurs in green plants all the time.       |
|                                                 | 21.43  17.86 21.43                                         |
|                                                 | 28 Photosynthesis occurs all the time.                      |
|                                                 | 17.86 14.29 10.71                                          |

*Note.* The relationship between the misconception number, the test item number and the test distractor can be seen in Appendix C.

The mean frequency of misconceptions was reduced from 23.34% in the pretest, to 8.93% in the posttest and to 9.19% in the delayed posttest. Twenty-five of the 28 misconceptions had a lower frequency in both the posttest and delayed posttest, than in the pretest. On a few of the items there was some regression to misconceptions between the posttest and the delayed posttest.
Four key misconception areas (KMC) reported in the literature (Anderson et al., 1986; Haslam & Treagust, 1987; Seymour & Longden, 1991) as being significant barriers to a scientific understanding of respiration have also featured prominently in Table 3. These are:

KMC 1. respiration is synonymous with breathing (misconception 5, in Table 3);

KMC 2. plants derive energy from sources other than food and oxygen (misconceptions 11, 12, 13 and 14);

KMC 3. respiration occurs only in certain parts of an organism (misconceptions 15, 16 and 17); and

KMC 4. plants do not respire continually (misconceptions 18, 19, 20, 21 and 22).

Four Key Misconception Areas

The following section will address the above key misconception areas and will incorporate quotations from the interviews showing the changes in student conceptions following instruction.

KMC 1. Respiration is Synonymous with Breathing

Table 3 showed that the percentage of students who confused respiration with breathing (misconception 5) dropped from 43% in the pretest, to 4% and 7% in the posttest and delayed posttest respectively. Table 4 presents summarised definitions of respiration which interviewed students held before, and after instruction.
TABLE 4
A Summary of Students' Interview Responses to the Question: "What does respiration mean to you?"

<table>
<thead>
<tr>
<th>Before instruction</th>
<th>After instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Breathing</td>
<td>Cellular process where food and oxygen gives energy, carbon dioxide and water.</td>
</tr>
<tr>
<td>2 Breathing, getting air and oxygen in</td>
<td>Cellular process which happens in the mitochondria.</td>
</tr>
<tr>
<td>3 Breathing</td>
<td>Cellular process where food and oxygen gives energy, carbon dioxide and water.</td>
</tr>
<tr>
<td>4 Breathing</td>
<td>The combining of food and oxygen in cells to obtain energy, carbon dioxide and water.</td>
</tr>
<tr>
<td>5 To breathe in and out</td>
<td>Cellular process where food and oxygen gives energy, carbon dioxide and water.</td>
</tr>
<tr>
<td>6 Breathing</td>
<td>When oxygen and food gives energy, carbon dioxide and water.</td>
</tr>
</tbody>
</table>

The following quotations from Student 1 and Student 4 were indicative of the responses given by most interviewed students. The number of dots (....) in the quotations indicates the length of pause by the speaker.

Student 1 Before instruction
I: "What does respiration mean to you?"
S: "It means uhm ... breathing. That's the first thing that comes to my head .. just breathing"

Student 1 After instruction
I: "What does respiration mean to you?"
S: "Uhm .. it's a cellular process, where food and oxygen ... combine .. to .. produce energy uhm .. water and carbon dioxide"
Student 4 Before instruction

I: "What could you look for to see if an animal was respiring?"

S: "To see if ... its chest or what ever went up and down"

Student 4 After instruction

I: "What could you look for to see if an animal was respiring?"

S: "If it's alive it respires"

Table 4 and the quotations show that during the pre instructional interviews students held the misconception that respiration was synonymous with breathing. In the post instructional interviews, however, all students were able to give a scientific definition of respiration.

KMC 2. Plants Derive Energy From Sources Other than Respiration (Combining Food and Oxygen)

Misconceptions 11-14 in Table 3 show that before instruction a noticeable percentage of students held the misconceptions that energy came directly from photosynthesis, oxygen or carbon dioxide. These misconceptions were examined more closely during the interviews, and the results are presented in Table 5 and Table 6, with accompanying quotations.

Table 5 summarises students' understanding of where an organism's energy comes from.
### TABLE 5
A Summary of Students' Interview Responses to the Question: "Where does the energy that organisms use to grow, etc come from?"

<table>
<thead>
<tr>
<th>Std</th>
<th>Before Instruction</th>
<th>After Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Food</td>
<td>Food</td>
</tr>
<tr>
<td>2</td>
<td>Water, sunlight and air</td>
<td>Food</td>
</tr>
<tr>
<td>3</td>
<td>Water</td>
<td>Food</td>
</tr>
<tr>
<td>4</td>
<td>Food and oxygen</td>
<td>Food and oxygen</td>
</tr>
<tr>
<td>5</td>
<td>Water and air</td>
<td>Sleeping</td>
</tr>
<tr>
<td>6</td>
<td>Water</td>
<td>Food</td>
</tr>
</tbody>
</table>

Note. Where the response has been summarised to 'respiration', these students clarified that respiration was the combining of food and oxygen to obtain energy.

The above table, and the quotations to follow show that before instruction, the interviewed students thought that plants obtained energy from the 'foods' they take in from their surroundings. After instruction, all but one stated that energy in plants and animals is derived from the process of respiration where food and oxygen are combined. Changes in students' thinking are exemplified by Student 2's quotations below.

**Before instruction:**

I: "Where does the energy that an animal uses to grow, etc come from?"

S: "The food that I eat .... no stress ... I don't know"

**After instruction**

I: "Where does the energy that an animal uses to grow, etc come from?"

S: "Food plus oxygen gives us energy, carbon dioxide and water"

I: "And what is that equation?"

S: "The respiration equation"
Before instruction
I: "Where does the energy that a plant uses to grow, etc come from?"
S: "From the water when we water it and the sunlight and the air that we breathe"
I: "How does the water give it energy?"
S: "Don't know"
I: "Any idea how the air gives it energy?"
S: "Not sure"
I: "Any idea how the sunlight gives it energy?"
S: "It shines on the plant" (could not expand on this)

After instruction
I: "Where does the energy that a plant uses to grow, etc come from?"
S: "Respiration"

Table 6 and the quotations have been presented to indicate students' understanding of the role of oxygen in respiration and to examine the misconception that energy is extracted from oxygen, which was relatively prominent in this study.

TABLE 6
A Summary of Students' Interview Responses to the Question: "Why do we need oxygen?"

<table>
<thead>
<tr>
<th>Student</th>
<th>Before instruction</th>
<th>After instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Don't know</td>
<td>To respire</td>
</tr>
<tr>
<td>2</td>
<td>To live</td>
<td>To live</td>
</tr>
<tr>
<td>3</td>
<td>Don't know</td>
<td>To live</td>
</tr>
<tr>
<td>4</td>
<td>To live</td>
<td>It can combine with food to give us energy</td>
</tr>
<tr>
<td>5</td>
<td>Don't know</td>
<td>To facilitate respiration</td>
</tr>
<tr>
<td>6</td>
<td>To live</td>
<td>To live</td>
</tr>
</tbody>
</table>
Students who responded 'to live' in Table 6 could not explain how oxygen enables organisms to live. The table shows that before instruction no student related the need for oxygen to respiration. After instruction only three interviewed students showed the ability to link an organism's need for oxygen (i.e. breathing) with the process of respiration. The following quotations illustrate Student 4's ability to make this link.

**Before instruction**

I: "Do the cells need anything that we breathe in?"
S: "They need the oxygen"
I: "Why do they need the oxygen do you think?"
S: "For energy"
I: "How does the oxygen give the cell energy?"
S: "Don't know"

**After instruction**

I: "Why do organisms breathe?"
S: "They breathe to get the oxygen they need to get the energy"
I: "How does the oxygen help to get the energy?"
S: "They combine it with food to get energy"
I: "And what is that process called?"
S: "Respiration"
KMC 3. Respiration Occurs Only in Certain Parts of Organisms

Table 7 summarises students' understanding of where respiration occurs in plants and animals.

<table>
<thead>
<tr>
<th>Before instruction</th>
<th>After instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Animal</strong></td>
<td><strong>Plant</strong></td>
</tr>
<tr>
<td>1</td>
<td>Lungs</td>
</tr>
<tr>
<td>2</td>
<td>Mouth, lungs, heart</td>
</tr>
<tr>
<td>3</td>
<td>Mouth and lungs</td>
</tr>
<tr>
<td>4</td>
<td>Lungs, where we get oxygen from</td>
</tr>
<tr>
<td>5</td>
<td>Mouth, lungs</td>
</tr>
<tr>
<td>6</td>
<td>In the body, heart</td>
</tr>
</tbody>
</table>

The data above support the findings presented in Table 3 (misconceptions 15-17) and indicate that before instruction most students confused respiration with breathing and hence held the misconception that respiration occurs in the lungs, and in the parts of a plant responsible for the intake of gases. After instruction all students demonstrated an understanding that respiration occurs in all cells of all organisms, plant or animal. The following quotations from Student 4 exemplifies the responses given by the interviewed students.
Before instruction
I: "Where in an animal does respiration occur?"
S: "The lungs ... or... yeah the lungs"
I: "Why do you say the lungs?"
S: "The lungs is kind of like where we store or get it from"
I: "Get what from?"
S: "Oxygen"

After instruction
I: "What sort of things respire?"
S: "All living things"
I: "Where does respiration occur?"
S: "In the cells"
I: "Which cells?"
S: "All the cells"

KMC 4. Plants Do Not Respire Continually
Students' understanding of when plants respire has been summarized in Table 8.

<table>
<thead>
<tr>
<th>Student</th>
<th>Before instruction</th>
<th>After instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not sure</td>
<td>Day and night</td>
</tr>
<tr>
<td>2</td>
<td>Day time</td>
<td>Day and night</td>
</tr>
<tr>
<td>3</td>
<td>Probably day, and night?</td>
<td>All the time</td>
</tr>
<tr>
<td>4</td>
<td>Day and night</td>
<td>Day and night</td>
</tr>
<tr>
<td>5</td>
<td>When they need to</td>
<td>Day and night</td>
</tr>
<tr>
<td>6</td>
<td>Night time</td>
<td>Day and night</td>
</tr>
</tbody>
</table>
The above table reflects the findings presented in Table 3 (misconceptions 18-22) as it shows that it was only after instruction that all the interviewed students demonstrated an awareness that respiration is a continuous process in plants. Student 6's quotations below, typified the change of conception demonstrated by most interviewed students.

**Before instruction**

I: "When do you think a plant would respire?"
S: "At night"
I: "What about during the day?"
S: "Uhm ... probably"
I: "Why do you think that respiration might only happen at night?"
S: "... Because ............... (could not say) .."

**After instruction**

I: "When do you think a plant would respire?"
S: "Day and night"

Convergent Validity Between Interview and Test Data

The responses of the six interviewed students to questions on the pencil and paper tests, and the interviews were compared. Comparisons were made on those questions that probed the four key misconception areas addressed in this study. The proportion of responses on the tests and interviews that were in agreement was 0.77 which indicates a satisfactory level of convergent validity between the two data sources (see Appendix B).
Comparing Frequencies of Misconceptions
With Past Research

Using the test items selected from Haslam and Treagust's (1987) study, Table 9 compares the frequency of misconceptions of respiration and photosynthesis in plants, evident in Morgillo's study after teaching for conceptual change, with the frequency of misconceptions reported by Haslam and Treagust in Year 8 students after traditional instruction. All misconceptions reported by Haslam and Treagust have been compared except for five which related to questions not used in Morgillo's study. The wording of the misconceptions and their order of recording correspond to Haslam and Treagust's, who used the distractors on the pencil and paper test to describe each misconception.

TABLE 9
Frequency of Posttest Misconceptions of Photosynthesis and Respiration in Plants, Reported by Morgillo (1993) and Haslam and Treagust (1987)

<table>
<thead>
<tr>
<th>Number Misconception Identified</th>
<th>Percentage of Students With Misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haslam and Treagust Year 8 (n=28)</td>
</tr>
<tr>
<td>18 Respiration in green plants takes place only during the day.</td>
<td>10.7</td>
</tr>
<tr>
<td>19 Respiration does not take place in the presence of light energy.</td>
<td>10.7</td>
</tr>
<tr>
<td>29 Carbon dioxide is given off in largest amounts by green plants in the presence of sunlight.</td>
<td>0.0</td>
</tr>
<tr>
<td>27 Photosynthesis occurs in green plants all the time.</td>
<td>17.9</td>
</tr>
<tr>
<td>30 Photosynthesis can occur in green plants when there is no light energy.</td>
<td>17.9</td>
</tr>
<tr>
<td>30 Carbon dioxide is used in respiration when there is no light energy to photosynthesis.</td>
<td>0.0</td>
</tr>
<tr>
<td>31 Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesis.</td>
<td>10.7</td>
</tr>
</tbody>
</table>
9 Green plants stop photosynthesizing when there is no light energy at all so they continue to respire and give off oxygen gas. 25.0 21.2
20 Green plants respire only when there is no light energy. 7.1 17.5
17 Respiration in plants takes place in the cells of leaves since only leaves have special pores to exchange gases. 14.3 29.2
32 Respiration in green plants is a chemical process to obtain energy which occurs in plant cells but not in animal cells. 3.6 5.0
33 Respiration in green plants provides energy to live and is a chemical process by which plants manufacture food from water and carbon dioxide. 7.1 10.9
7 Respiration in green plants is the taking in of carbon dioxide and giving off of oxygen gas through plant stomates. 3.6 18.2
21 Green plants respire only at night (when there is no light energy). 7.1 24.1
34 During respiration carbon dioxide and water are used by green plants to produce energy, during which time glucose and oxygen waste are produced. 3.6 15.3
35 Respiration takes place in all plants only when there is no light energy and in animals all the time. 0.0 22.6

Note. a The numbers correspond to the misconception numbers assigned in Table 3 of this chapter. Misconceptions 29-35 were not included in Table 3 as their frequency did not exceed the required 10.71% on the pretest.

Fifteen of the 16 misconceptions listed above had a lower frequency in Morgillo's posttest than Haslam and Treagust's. The mean percentage of misconceptions was 8.71 in Morgillo's posttest, compared with 18.69 in Haslam and Treagust's study.

Students' Awareness that the Term 'Respiration' is Used Differently by Different Groups of People

Table 10 presents a summary of responses that illustrates the extent to which interviewed students were aware that different people might interpret or use the word 'respiration' differently.
### TABLE 10
A Summary of Students' Interview Responses to the Question: "What meaning would the following persons associate with respiration?"

<table>
<thead>
<tr>
<th>Before instruction</th>
<th>After instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Std Lay person</strong></td>
<td><strong>Nurse/Doctor</strong></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>&quot;I don't really know what respiration is so I can't say&quot;</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Don't know but the scientist would know the most</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Don't know</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Would depend on their schooling</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Would depend on their excrete in and out schooling</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>It might have different meanings</td>
</tr>
</tbody>
</table>

The following quotations illustrate the change in Student 4's awareness that different groups of people hold different meanings of respiration.

**Before instruction**

I: "If I had three people, a shop assistant, a nurse or doctor and a scientist, and used the word 'breathing', do you think they would picture the same process?"

S: "They might .... and they might not"

I: "Why do you think they might not?"
S: "Because ..... people have got different pictures of what breathing might mean"

I: "If I said the word 'respiration' do you think the shop assistant, the doctor or nurse, and the scientist would be thinking the same thing?"

S: "They might be thinking something different or they might be thinking of the same thing"

I: "Do you think it might be more different than breathing?"

S: "Yep!"

I: "Why do you think that might be the case?"

S: "Because ..... respiration you don't really hear ...
like .. you don't really hear a lot like with breathing, you sometimes you learn when you're .... young like when you're in Year ... about ..... even in pre school you might learn about that so it's like a common word while respiration is kind of a .. you won't hear it often"

I: "In what ways do you think the views on respiration might be different?"

S: "The scientist would probably know more about respiration because that's what ... they do, they study science and all that. The doctor .. study .. like .. if something's wrong with you .. you can't breathe properly .. they .. they would know a bit about that ... different than what the scientist does and the shop assistant would know what she does or learnt"

After instruction

I: "Do you think different people might use the word 'respiration' differently?"

S: "Yeah"
I: "What sort of people do you think might use it differently?"
S: "Uhm ... scientists, uh, medical profession, and normal people like everyday people"
I: "The normal person, what do you think he or she might think respiration means?"
S: "Breathing"
I: "What about the nurse or doctor?"
S: "They'd say, uhm, it was cellular respiration"
I: "A scientist?"
S: "A scientist would say its just respiration"
I: "And what is respiration to them?"
S: "Uhm, food and oxygen combines to make energy, carbon dioxide and water"

The above extract was typical of most students' responses, who during the pre instruction interviews were unaware of the types of meaning commonly associated with respiration. However, most did state that they suspected people might hold different meanings of respiration, depending on their education and/or occupation. In the post instruction interviews, most students were able to state that lay people and medical personnel are likely to associate respiration with breathing, whereas scientists would interpret respiration as an energy releasing cellular process which is different from breathing.
CHAPTER 5

DISCUSSION

While bearing in mind the dangers of generalising from a small sample size and comparing unmatched groups, this chapter will establish whether the conceptual change teaching strategy achieved its objectives.

Students' Understanding of Respiration, Gaseous Exchange and the Relationship Between Respiration and Photosynthesis

Students' understanding of respiration, gaseous exchange and the relationship between respiration and photosynthesis were assessed using a pencil and paper test. The mean pretest (3.82), posttest (10.50), and delayed posttest (10.25) scores indicate a significant improvement in scientific conceptions following instruction, and a small regression four weeks after instruction.

Students' Understanding of Respiration

If students are to understand respiration from a scientist's perspective they should be able to define it by way of equation, indicating that food and oxygen combine to release energy, water and carbon dioxide, and state that it is an ongoing process in all cells of all organisms. Students' understanding of these key aspects is discussed below.
1. Defining Respiration

The open-ended question of this study (Test item A) revealed that before instruction no student could accurately define respiration, whereas 96% could after teaching for conceptual change. Similarly the interviewed students thought respiration was breathing before instruction, whereas all six students gave a scientific definition of respiration, after instruction. These results compare favourably with studies from Anderson et al. (1986) who reported that only 31% of tertiary students could accurately define respiration, and Eisen and Stavy (1988) who reported that 71% of tertiary biology majors and only 8% of non-biology majors could define respiration at the level expected from Morgillo's Year 8 sample.

2. Energy is Derived from Food Which Combines With Oxygen

Forty-six per cent of the experimental group claimed that food was respiration's source of energy in the multiple choice test. Although this compared well with the 26% of Year 11's reported by Seymour and Longden (1991) using the same test item, it is not consistent with the finding that 96% of Morgillo's sample accurately defined respiration in terms of a reaction between oxygen and food, or the finding that after instruction most of the interviewed students (Table 5) stated that energy was derived from respiration which uses food and oxygen. The reason for this anomaly may have been clarified by some of the interviewed students who explained that they did not
choose the correct multiple choice responses because they did not understand the word 'oxidation'.

Although it could be argued that the process of oxidation should have been taught in some detail, it was thought that this topic may have been beyond the students' capabilities, and that it was not essential at Year 8 level. This line of reasoning is supported by Eisen and Stavy's finding that only 18% of tertiary biology majors and 2% of non-biology majors could state that respiration was both the oxidation of food and the release of energy.

The omission of 'high information' situations when concepts are first being introduced in the teaching of respiration has been advocated by Seymour and Longden. However, the results of Morgillo's study indicate that the omission of the oxidation process from instruction may have restricted students' understanding that food, rather than oxygen, is the source of energy during respiration.

3. Respiration Occurs in All Cells

The percentage of students who claimed that respiration occurs in all cells (test item 9) increased from 32% before instruction, to 93% after instruction. This result compares favourably with the 52% of the Year 11 sample reported in Seymour and Longden's study, using the same test item. Interview data presented in Table 7 also showed that before instruction students typically nominated regions of respiration to be where they suspected
an organism breathed. After instruction however, all the interviewed students, in essence, stated that respiration occurred in all cells of plants and animals.

4. Respiration is an Ongoing Process

The percentage of students who stated that respiration was an ongoing process in plants (test item 6) increased from 7% to 64% in this study. This result compares favourably with the 31% of Year 11 students, reported by Seymour and Longden, who responded correctly on the same test item following traditional instruction. Furthermore, after teaching for conceptual change, all the interviewed students (Table 8) stated that respiration is an ongoing process in plants.

Comparing Students' Understanding of 'Difficult' Concepts Within the Topics of Respiration and Gaseous Exchange with Past Research Findings

Table 2 compared the correct response percentages of concepts which Seymour and Longden's test showed were poorly understood after traditional instruction. Using the same test items it was found that Morgillo's Year 8 experimental group achieved higher frequencies in five of the six concepts reported in Seymour and Longden's Year 11 sample, and that the experimental group also achieved a mean score of 54%, which compared favourably with the 38% recorded by Seymour and Longden's Year 11 sample.
The above discussion suggests that the conceptual change strategy was successful in enhancing students' understanding of respiration; the relationship between respiration and photosynthesis; and concepts within the topics of respiration and gaseous exchange which past research has shown to be poorly understood after traditional instruction.

Misconceptions of Respiration, Gaseous Exchange and the Relationship Between Respiration and Photosynthesis

The mean frequency of misconceptions associated with an overall understanding of respiration, gaseous exchange and the relationship between respiration and photosynthesis was reduced from 23.34% in the pretest, to 8.93% in the posttest and to 9.19% in the delayed posttest (Table 3). Twenty-five of the 28 misconceptions had a lower frequency in both the posttest and delayed posttest, than in the pretest. No misconception had a higher frequency in the delayed posttest than in the pretest. This reduction in misconceptions coincides with the increased mean frequencies of correct responses reported in Table 1.

Four key misconception areas (KMC), which the literature has shown to be common are discussed in the following pages.
Four Key Misconception Areas of Respiration

KMC 1. Respiration is Synonymous with Breathing

The most common misconception evident before instruction was that respiration is synonymous with breathing. This misconception has also been reported to be held by 50% of 12-16 year olds (Simpson & Arnold, 1982a), 32% of Year 11 students (Seymour & Longden, 1991), 80% of university non-biology majors (Anderson et al. 1986) and 39% of university biology majors (Eisen & Stavy, 1988).

After teaching for conceptual change, the frequency of this misconception (number 5, in Table 3) was reduced from 43% to 4%, which is far less than the studies cited above. This result is supported by the interview data (Table 4), and indicates that the conceptual change strategy was successful in alleviating this misconception, which other studies have shown persists after traditional instruction.

KMC 2. Energy is Acquired From Sources Other than Respiration (Combining Food and Oxygen)

The misconception that plants photosynthesize to produce usable energy (number 11, in Table 3) was reduced in Morgillo's study from 29% to 0%. Because a different test item was used to identify this misconception by Haslam and Treagust the frequencies should not be compared. However, it is evident that while the frequency of this misconception was reduced in this study, Haslam and
Treagust reported that it increased in Years 8 (22%), 9 (28%), 10 (30%) and 11 (34%), to be 31% in Year 12, where traditional teaching methods had been used.

The misconception that organisms acquire energy from carbon dioxide (number 14) was reduced from 14% to 11%, after teaching for conceptual change. This can be indirectly compared with Eisen and Stavy's study which found 29% of tertiary biology majors thought this gas was a plant's food source.

Although not prominent in other studies, the misconception that organisms acquire their energy from oxygen (number 13) was reduced from 29% to 14% after teaching for conceptual change. As discussed earlier the incidence of this misconception may have been attributed to a poor understanding of the oxidation process by the experimental group.

Before instruction a number of interviewed students claimed that plants obtained energy from sources such as water and air (Table 5). After teaching for conceptual change, however, most interviewed students stated that respiration (the combining of food and oxygen) was the process whereby organisms obtained their energy. The origin of these types of misconceptions is partly explained by Bell (1985) who reported that the word 'food' was often associated with the word 'energy'. Consequently, students who think of water or carbon dioxide as a food source for plants, are likely to consider it as an energy source.
This problem is compounded as students from primary (Bell, 1985) to tertiary levels (Eisen & Stavy, 1988) hold misconceptions about a plant's food source. The reduced frequency of the above mentioned misconceptions, and the interview data suggest that the implemented conceptual change strategy was comparatively successful in minimising misconceptions about an organism's source of energy.

KMC 3. Respiration Occurs Only in Certain Parts of An Organism

The second most frequent misconception evident in this study before instruction was that respiration occurs only in the lungs (number 15, in Table 3). After teaching for conceptual change the incidence of this misconception was reduced from 36% to only 4%, which compares well to 57% the highest reported by Seymour and Longden. Similarly, Haslam and Treagust, reported that the most common misconception in Years 8 (29%), 9 (47%), 10 (41%) and 11 (34%) was that respiration in plants occurs only in the leaves. The persistent high levels of this misconception (and others) reported by Haslam and Treagust, which was more prominent in Years 9-11 than in Year 8, suggest that traditional teaching methods are not effective in reducing misconceptions. This misconception (number 17) was relatively infrequent (14% in the pretest and posttest) in Morgillo's sample who attempted the same test item as Haslam and Treagust's samples. Although before instruction most of the interviewed students in Morgillo's study stated that respiration occurs in regions where an organism
presumably breathes, after instruction all six stated that respiration occurs in all plant and animal cells.

KMC 4. Plants Do Not Respire Continually

The frequencies of misconception numbers 18-22 presented in Table 3 illustrated students' lack of understanding, before instruction, about when plants respire. Misconception 21 was reduced from 21% to 7% in Morgillo's Year 8 sample which compares favourably with the Year 8 (24%), 9 (42%), 10 (34%), 11 (24%) and 12 (12%) results reported by Haslam and Treagust, using the same test item. Other comparisons, where the same test items were again used, also showed that whereas the frequency of these type of misconceptions were reduced in Morgillo's study, after teaching for conceptual change, they persisted and in some cases increased in Haslam and Treagust's study where traditional instruction was used. The above findings, which suggest that the conceptual change strategy was successful in reducing the incidence of misconceptions about when a plant respires, were supported by the interview data in Table 8.

Frequencies of Misconceptions About Respiration and Photosynthesis in Plants Compared with Past Research

Using nine of the thirteen test items from Haslam and Treagust's (1986) study, Table 9 showed that Morgillo's Year 8 group had a lower frequency in 15 of 16 misconceptions about respiration and photosynthesis in
plants, than Haslam and Treagust's Year 8 sample. In addition, Haslam and Treagust's study showed that the mean frequency of these 16 misconceptions persisted in Years 8 (18.7%), 9 (21.7%), 10 (20.9%) and 11 (16.3%) despite respiration being taught in Years 8-10. Contrary to this finding, Morgillo's Year 8 experimental group's mean frequency of the same misconceptions was reduced from 15.9% to 8.4% after teaching for conceptual change.

Even though the groups are not matched, the Year 8 experimental group often appeared to out-perform other Year 8, 9, 10 and 11 samples. This suggests that the conceptual change strategy was successful in reducing the incidence of misconceptions about respiration and photosynthesis in plants, evident after traditional instruction.

Students' Awareness that the Term 'Respiration' is Used Differently by Different Groups of People

Before instruction the interviewed students could not state how the term 'respiration' might be used differently. However, after instruction they were all aware of the scientific interpretation of respiration; that respiration was often confused with breathing by the lay person; and that the medical interpretation of respiration was also different from that of the scientist. Teacher-student interaction and classroom observations revealed that the interview findings were, in essence, reflected by the entire Year 8 group.
Apparent Attributes of the Conceptual Change Strategy

Previous studies have shown clearly that misconceptions about respiration persist at secondary and tertiary level despite formal instruction, and regardless of the amount of biology studied, yet that was not the case after teaching for conceptual change. The results of this study suggest that a teaching strategy based on conceptual change models can develop in students a scientific understanding of respiration, reduce the incidence of misconceptions associated with this topic and develop an awareness that the term 'respiration' is used differently by lay, medical and scientific persons.

It is suggested that the success of the conceptual change strategy can be attributed to the use of a constructivist approach, where the teacher took the necessary steps to become informed of the potential problems concerned with the topic, and where students' entering knowledge could be linked to new information in a meaningful way. Using specifically designed strategies students discovered for themselves that respiration had more than one meaning, and the limitations of the lay and medical meanings. Such strategies included a definition search which revealed that reputable textbooks did not agree on the meaning of respiration and students conducting personal interviews to establish adults' understanding of respiration. These strategies appeared to have provided a catalyst for meaningful learning, where students were
prepared to be open minded about the different meanings associated with respiration.

Common misconceptions and their possible origin were explicitly addressed during instruction and this was supported by specific written materials, which also helped to address essential related topics. The selection of key ideas from a variety of conceptual change models provided students with every opportunity possible to develop a scientific understanding of respiration, yet still appreciate its everyday and medical meaning. Having focused on and alleviated the misconception that respiration is synonymous with breathing, it was not surprising to find that the incidence of a number of other misconceptions was also reduced considerably. However, the results do indicate that although an emphasis on clarifying the difference between respiration and breathing appeared to have been a successful strategy, 'equal' emphasis should have also been given to the dependence of these two processes on each other.
CHAPTER 6

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

Summary of Results

Before teaching for conceptual change, the experimental group like other secondary and university students in England, America, Israel and Australia demonstrated a lack of understanding and held misconceptions about respiration. Students were generally unaware that respiration is an ongoing energy releasing process requiring food and oxygen, which occurs in all living cells of organisms. The problem has been attributed to the everyday meaning of the word, poor text material, the abstractness of the concept, a poor understanding of related topics, inadequate teaching strategies and a science curriculum which world-wide has failed to address students' alternative frameworks that are brought to instruction.

Although a number of studies have identified and described misconceptions about respiration, there is a noticeable absence of research that attempts to confront these problems at the secondary level. Consequently, a four phase conceptual change teaching strategy with the aid of specifically written materials was implemented with a mainstreamed group of Year 8 students, none of whom had held a scientifically acceptable concept of respiration before instruction.
The results of this study in relation to the five research questions are summarised as follows.

To what extent can a conceptual change teaching strategy based on conceptual change models:

1. **Develop in Year 8 students an acceptable scientific conception of respiration.** The frequency of students who were able to define respiration as a process where food and oxygen combine to release energy, water and carbon dioxide increased from 0% in the pretest to 96% after teaching for conceptual change. Those who stated that respiration was an ongoing process in plants increased from 7% to 64%, and the frequency of students who could state that respiration occurs in all cells increased from 32% to 93%. These results and those of Research Questions 2, 3, 4 and 5, suggest that the conceptual change strategy was successful in developing in students an acceptable scientific conception of respiration.

2. **Alleviate the misconception that respiration is synonymous with breathing.** The incidence of this misconception was reduced from 43% in the pretest to 4% in the posttest and to 7% in the delayed posttest, indicating that it was alleviated.

3. **Develop an awareness in Year 8 students that the term 'respiration' is often interpreted and used differently by the lay, medical and scientific communities.** Interview responses and classroom student-teacher interaction clearly indicated that students did develop this awareness.
4. Reduce the incidence of misconceptions relating to respiration and photosynthesis in plants, which the literature has associated with traditional instruction. The incidence of these misconceptions in the Year 8 experimental group was reduced after teaching for conceptual change. It was also generally found, using the same test items, that these frequencies were less than those reported by Haslam and Treagust, of similar year groups and in some cases year groups well beyond their own, which had received traditional instruction.

5. Enhance students' understanding of key concepts within the topics of respiration and gaseous exchange, which the literature suggests is poorly understood as a result of traditional instruction. Seymour and Longden's (1991) Year 11 sample revealed concepts within the topics of respiration and gaseous exchange which were poorly understood after traditional instruction. The results of Morgillo's study showed that the Year 8's performance on these concepts improved after teaching for conceptual change, and that the experimental group also fared better than Seymour and Longden's Year 11 sample on these concepts, using the same test items.
Limitations

It should be reiterated that this exploratory study had a number of limitations. The experimental group was an intact class of only 28 students and may have not been representative of the general Year 8 population. Where results have been compared to other studies, the samples were not matched: they varied in size; some year groups differed; instructional time on the topic may have varied; testing conditions would not have been identical; and the duration between instruction and the posttest in previous studies could have been considerably longer than the time lapse used with the experimental group.

Limitations, however, are an inevitable part of research and they should not totally detract from the worthwhile findings of this study. Wherever it was possible to make comparisons with previous studies, using the same test items, the Year 8 experimental group frequently out-performed other groups of students up to Year 11 level.
Implications and Recommendations

For Educators

Science educators at all levels need to be aware of the alternative frameworks which students bring with them to the classroom, and the types of misconceptions which are commonly associated with a topic. They need to realize that these misconceptions are tenacious and that related concepts also need to be comprehended if students are to understand the concept being taught. In-service courses and publications by science education organisations such as the Science Teachers Association of Western Australia could enhance teachers' awareness of common misconceptions, their origin, how they can be identified and possible strategies to overcome these problems.

In teaching for conceptual change a constructivist approach should be used where students are encouraged to construct knowledge for themselves, and where students' entering behaviour is established to ensure new and old information is linked.

For Textbook Writers

Although most textbooks explain respiration and breathing scientifically, they have as their main diagram a set of lungs under the heading 'The Respiratory System'. This may in fact reinforce the misconception that respiration is synonymous with breathing. Ideally
textbooks should use the heading 'Breathing System' to explain that process, and then present a section on respiration focusing on energy release in plant and animal cells. The processes of breathing and respiration should be compared and contrasted, and their dependence on each other made explicit, both in textbooks and by teachers.

The language used by textbook authors, teachers and curriculum writers must be precise, and only those concepts within the intellectual capabilities of students should be addressed to avoid further confusion.

For Curriculum Writers

The National Statement on Science for Australian Schools (1992) has stated its commitment to constructivism and has acknowledged that the tenacious characteristics of students' alternative frameworks should provide the starting point for instruction. This document has also acknowledged the need to explore key concepts in depth and the need for a curriculum to value and address both scientific and lay interpretations of scientific concepts.

It is recommended that curriculum materials developed at national and state levels help teachers identify, and subsequently confront commonly held misconceptions by making students aware of these alternative frameworks and their possible origin. If students are to learn effectively in science, teachers and curriculum designers need to consider carefully the context in which ideas are
presented as this helps students to link science concepts and processes to their own experience, and thus enhances learning.

This study has indicated that teachers can successfully teach for conceptual change. However, without a clear direction and commitment from curriculum writers by way of specified objectives and support materials, teachers are not likely to address, or be aware of, students' misconceptions. Consequently, these problems are likely to persist in science classes despite the teacher's very best intentions to promote meaningful learning.

For Future Research

It is proposed that the encouraging results achieved in this study justify the need for further research. Such research would ideally have a larger and more diverse sample of carefully selected experimental and control groups to more clearly ascertain the conceptual change teaching strategy's effectiveness in bringing about significant and long lasting conceptual change.

The conceptual change strategy used in this study was designed specifically to overcome problems typically associated with respiration. An important test for the strategy would be to determine its effectiveness with other topics such as energy, force, work, animal, soil and food where, like respiration, the everyday meaning is confused with the scientific conception.
REFERENCES


APPENDIX A

Seventeen Item Test Instrument

Open-ended question (i.e. number 'A') used in Morgillo's (1993) study

NAME: ________________________________

Answer the following question then complete the 16 multiple choice questions.

**Question 'A'** When you hear the word 'respiration' what does it mean to you?

**Answer** In my opinion respiration means:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Sixteen Two-tier Multiple Choice Test Items Used in Morgillo's Study

NAME: __________________________________________________________

TOPIC TEST

Instructions.
The questions in this test are composed of two parts.
In the first part, circle the answer which you think is correct.
In the second part, circle the alternative which best describes the reason for your choice in part one.
If none of the alternatives is suitable, write your own reason under the alternative marked 'other'.
Answer the questions in order. Do NOT back track.

1. Air breathed out by animals contains:
   1. Carbon dioxide only.
   2. Carbon dioxide and nitrogen only.
   3. Carbon dioxide, nitrogen and oxygen.

   The reason for my answer is:

   (a) During breathing all of the oxygen is absorbed and is replaced by carbon dioxide. Nitrogen in the air is unaffected.

   (b) During breathing all of the oxygen and all of the nitrogen is absorbed. Carbon dioxide only is breathed out.

   (c) During breathing some of the oxygen is absorbed but not all. A small amount of carbon dioxide is released. Nitrogen is unaffected.

   (d) Other: __________________________________________
2. Which gas is taken in by green plants in a large amount when there is no light energy at all?

1. Carbon dioxide gas
2. Oxygen gas

The reason for my answer is:

(a) This gas is used in photosynthesis which occurs in green plants all the time.

(b) This gas is used in photosynthesis which occurs in green plants when there is no light energy at all.

(c) This gas is used in respiration which occurs in green plants when there is no light energy to photosynthesise.

(d) This gas is used in respiration which taken place continuously in green plants.

(e) Other: ______________________________

3. Which gas is given off by green plants in large amounts when there is no light energy at all?

1. Carbon dioxide gas.
2. Oxygen gas.

The reason for my answer is:

(a) Green plants stop photosynthesising when there is no light energy at all so they continue to respire and therefore they give off this gas.

(b) This gas is given off by green plants during photosynthesis which takes place when there is no light energy.

(c) Since green plants respire only when there is no light energy they give off this gas.

(d) Other: ______________________________
4. Which of the following gases are carried in the blood:

1. Oxygen only.
2. Oxygen and carbon dioxide.
3. Neither oxygen or carbon dioxide.

The reason for my answer is:

(a) The blood does not carry gases.

(b) The blood carries oxygen around the body in the form of oxyhaemoglobin. It is unable to carry carbon dioxide.

(c) The blood carries oxygen from the lungs to the cells and carbon dioxide from the cells to the lungs.

(d) Other: ____________________________

5. What gas is given out in largest amounts by green plants in the presence of sunlight?

1. Carbon dioxide gas.
2. Oxygen gas.

The reason for my answer is:

(a) This gas is given off in the presence of light energy because green plants only respire during the day.

(b) This gas is given off by the green plant because green plants only photosynthesise and do not respire in the presence of light energy.

(c) There is more of this gas produced by the green plant during photosynthesis than is required by the green plant for respiration and other processes, so that excess gas is given off.

(d) This gas is a waste product given off by green plant after they photosynthesise.

(e) Other: ____________________________
6 Which gas is taken in by green plants in darkness?

1. Oxygen
2. carbon dioxide

The reason for my answer is:

(a) This gas is used in photosynthesis which occurs only in darkness.

(b) This gas is used in photosynthesis which occurs all of the time.

(c) This gas is used in respiration which only occurs in darkness.

(d) This gas is used in respiration which occurs all of the time.

(e) Other: ________________________________

7. Which of the statements listed below is true?

1. Only mammals respire.
2. Animals respire, plants do not.
3. All living things, including animals and plants respire?

The reason for my answer is:

(a) All living things have a need for energy.

(b) Only mammals need to breathe.

(c) Animals breathe but plants do not.

(d) Other: ________________________________
8. Which of the following can be used as a source of energy for respiration?

1. Food.
2. Oxygen.
3. Carbon dioxide.

The reason for my answer is:

(a) This substance contains energy which can be released at the lung surface.

(b) This substance contains energy which can be released in the digestive system.

(c) This substance contains energy which can be released in the cells of the body.

(d) Other: ____________________________


9. Which of the following is true?

1. Energy release during respiration occurs only in the lungs.
2. Energy release during respiration occurs only in the stomach.
3. Energy release during respiration occurs in all cells of the body.

The reason for my answer is:

(a) All cells have an energy requirement and must respire.

(b) The lungs are the place where oxygen is taken into the body.

(c) The stomach is the place where food is digested.

(d) Other: ____________________________
10. Which of the following is true about respiration?

1. It involves the oxidation of food and release of energy.
2. It involves the extraction of energy from oxygen.
3. Energy is used to oxidise food.

The reason for my answer is:

(a) Food cannot be used by the body unless energy is used to break it down.

(b) Food contains chemical energy which can only be released by using oxygen to break it down.

(c) Oxygen contains chemical energy which can only be released by breaking it down.

(d) Other: ____________________________

11. Respiration in plants takes place in:

1. The cells of roots only.
2. In every plant cell.
3. In the cells of leaves only.

The reason for my answer is:

(a) All living cells need energy to live.

(b) Only leaves have special pores (stomates) to exchange gas.

(c) Only roots have small pores to breathe.

(d) Only roots need energy to absorb water.

(e) Other: ____________________________
12. Respiration is:
1. A chemical process which occurs in all living cells of plants and animals.
2. A chemical process which occurs in plants but not in animal cells.
3. A chemical process which occurs only in animal cells but not in plant cells.

The reason for my answer is:
(a) Only plant cells obtain energy to live in this way.
(b) All living cells of plants and animals obtain energy to live through this process.
(c) Only animal cells need energy to live as they cannot photosynthesise.
(d) Other: 

13. Which of the following is the most accurate statement about respiration in green plants?

1. It is a chemical process by which plants manufacture food from water and carbon dioxide.
2. It is a chemical process in which energy stored in food is released using oxygen.
3. It is the exchange of carbon dioxide and oxygen gases through plant's stomates.
4. It is a process that does not take place in green plant when photosynthesis is taking place.

The reason for my answer is:
(a) Green plants never respire they only photosynthesis.
(b) Green plants take in carbon dioxide and give off oxygen when they respire.
(c) Respiration provides the green plant with energy to live.
(d) Respiration only occurs in green plants when there is no light energy.
(e) Other: 

14. When do green plants respire?

1. Only at night (when there is no light energy).
2. Only during daylight (when there is no light energy).
3. All the time (whether there is light energy or there is no light energy).

The reason for my answer is:

(a) Cells of green plants can photosynthesise during the day when there is light energy and therefore they respire only at night when there is no light energy.

(b) Green plants need energy to live and respiration provides energy.

(c) Green plants do not respire they only photosynthesise, and photosynthesis provides energy for the plant.

(d) Other: ______________________________

______________________________
15. Which of the following comparisons between the processes of photosynthesis and respiration in green plants is correct?

Photosynthesis                        Respiration
1. Takes place in green plants only.  Takes place in animals only.
2. Takes place in all plants.         Takes place only in all animals.
3. Takes place in green plants in presence of light energy. Takes place in all plants and in all animals at all times.
4. Takes place in green plants in presence of light energy. Takes place in all plants only when there is no light energy and all the time in all animals.

The reason for my answer is:

(a) Green plants photosynthesise and do not respire at all.

(b) Green plants photosynthesise during the day and respire at night (when there is no light energy at all).

(c) Every living thing needs to respire to obtain energy. Green plants photosynthesise only during the day when there is light energy.

(d) Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesise.

(e) Other: ___________________________
16. Which of the following equations best represents the process of respiration in plants?

1. Glucose + oxygen ---> energy + carbon dioxide + water.
2. Carbon dioxide + water ---> energy + glucose + oxygen.

light energy
3. Carbon dioxide + water ----------> oxygen + glucose.
chlorophyll
4. Glucose + oxygen ----------> carbon dioxide + water.

The reason for my answer is:

(a) During respiration, green plants take in carbon dioxide and water in the presence of light energy to form glucose.

(b) Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.

(c) During respiration, green plants take in oxygen and give off carbon dioxide and water.

(d) During respiration, green plants derive energy from glucose using oxygen.

(e) Other: ____________________________

______________________________________
Correct Responses to Pencil and Paper Test

<table>
<thead>
<tr>
<th>Question</th>
<th>Correct response</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Respiration is a process where cells combine food and oxygen to release energy, carbon dioxide and water</td>
</tr>
</tbody>
</table>

1. 3 & C  
2. 2 & D  
3. 1 & A  
4. 2 & C  
5. 2 & C  
6. 1 & D  
7. 3 & A  
8. 1 & C  
9. 3 & A  
10. 1 & B  
11. 2 & A  
12. 1 & B  
13. 2 & C  
14. 3 & B  
15. 3 & C  
16. 1 & D

In the above multiple choice questions both tiers needed to be correctly selected to record a correct response.

Note

Test items: 1, 4, 6, 7, 8, 9, and 10 are from Seymour (1989, pp. 127-132).

Test items: 2, 3, 5, 11, 12, 13, 14, 15, and 16 are from Haslam (1987, pp. 247-253).
**APPENDIX B**

**Convergent Validity Test**

Convergent Validity of Data from Tests and Interviews

<table>
<thead>
<tr>
<th>Student</th>
<th>Misconception Number</th>
<th>Proportion of responses in agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>(a) pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>D</td>
</tr>
</tbody>
</table>

(b) posttest

|         |    |     |       |     |     |                                  |
| 1       | A  | A   | A     | A   | 1.0 |
| 2       | A  | A   | A     | A   | 1.0 |
| 3       | A  | A   | A     | A   | 1.0 |
| 4       | A  | D   | A     | A   | 0.8 |
| 5       | A  | D   | A     | A   | 0.8 |
| 6       | A  | A   | A     | D   | 0.8 |

P Agreement = 0.77

<table>
<thead>
<tr>
<th>Number</th>
<th>Corresponding Misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Respiration is synonymous with breathing.</td>
</tr>
<tr>
<td>11</td>
<td>Plants get energy from photosynthesis.</td>
</tr>
<tr>
<td>12</td>
<td>Energy acquired via respiration is extracted from oxygen.</td>
</tr>
<tr>
<td>13</td>
<td>Oxygen can be used as a source of energy for respiration.</td>
</tr>
<tr>
<td>15</td>
<td>Energy release during respiration occurs only in the lungs.</td>
</tr>
<tr>
<td>21</td>
<td>Green plants respire only at night (when there is no light energy).</td>
</tr>
</tbody>
</table>
APPENDIX C

Relationship Between Misconception Number (M/C No), Test Item Number (Test I/No) and Test Distractor (Test Dist).

<table>
<thead>
<tr>
<th>M/C No</th>
<th>Test I/No</th>
<th>Test Dist</th>
<th>Misconception Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>16a, 26a</td>
<td>During breathing all of the oxygen is absorbed and is replaced by carbon dioxide. Nitrogen in the air is unaffected.</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>14b</td>
<td>During breathing all of the oxygen and all of the nitrogen is absorbed. Carbon dioxide only is breathed out.</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>34a</td>
<td>The blood does not carry gases.</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>16b</td>
<td>The blood carries only oxygen.</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>*</td>
<td>Respiration is synonymous with breathing.</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>*</td>
<td>Respiration is synonymous with sweating.</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>34b</td>
<td>Respiration in green plants is the taking in of carbon dioxide and giving off of oxygen gas through plant’s stomata.</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>26c 26d</td>
<td>Carbon dioxide is used in respiration.</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>26a</td>
<td>Green plants stop photosynthesising when there is no light energy so they continue to respire and give off oxygen.</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>1, 2, b, c</td>
<td>Not all living things (animals and plants) need to respire.</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>c</td>
<td>Plants get energy from photosynthesis.</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>26c</td>
<td>Energy acquired via respiration is extracted from oxygen.</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td></td>
<td>Oxygen can be used as a source of energy for respiration.</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>3</td>
<td>Carbon dioxide can be used as a source of energy for respiration.</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>1</td>
<td>Respiration occurs only in the lungs (where energy is released).</td>
</tr>
<tr>
<td>16</td>
<td>9</td>
<td>2</td>
<td>Respiration occurs only in the stomach (where energy is released).</td>
</tr>
<tr>
<td>17</td>
<td>11</td>
<td>34b</td>
<td>Respiration in plants takes place in the cells of leaves only.</td>
</tr>
<tr>
<td>18</td>
<td>5</td>
<td>16a 26a</td>
<td>Respiration in green plants takes place only during the day.</td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td>16a 26b</td>
<td>Respiration in green plants does not take place in the presence of light energy.</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>16c 26c</td>
<td>Green plants respire only when there is no light energy.</td>
</tr>
<tr>
<td>21</td>
<td>14</td>
<td>16a 16b</td>
<td>Green plants respire only at night (when there is no light energy).</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
<td>16c</td>
<td>Carbon dioxide is used in respiration which occurs in green plants when there is no light energy to photosynthesise.</td>
</tr>
<tr>
<td>23</td>
<td>6</td>
<td>16a 26a</td>
<td>Photosynthesis only occurs at night.</td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>b</td>
<td>Photosynthesis occurs in green plants when there is no light energy.</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>26b</td>
<td>Oxygen is given off by green plants during photosynthesis which takes place when there is no light energy.</td>
</tr>
<tr>
<td>26</td>
<td>3</td>
<td>16b</td>
<td>Carbon dioxide is given off by green plants during photosynthesis which takes place when there is no light energy.</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>a</td>
<td>Photosynthesis occurs in green plants all the time.</td>
</tr>
<tr>
<td>28</td>
<td>6</td>
<td>16b 26b</td>
<td>Photosynthesis occurs all the time.</td>
</tr>
</tbody>
</table>

Note
* Responses from open-ended question.