The Development and Evaluation of A Computer-Assisted Instructional Strategy Designed to Change Student Misconceptions about Chemical Equilibrium

A RESEARCH PROPOSAL

Submitted

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By

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CONTENTS

ABSTRACT

Research in the past two decades indicate that misconceptions impede the acquisition of scientific conceptions and are resistant to change. A previous study has identified misconceptions about chemical equilibrium in WA students. The proposed research addresses those misconceptions and seeks to induce conceptual change about the topic using a computer-assisted teaching strategy.

A class of Year-12 students (in Maldives) will be exposed to traditional instruction in chemical equilibrium and their misconceptions identified by interviews and pencil and paper tests. Students will then work through a computer-assisted instruction (CAI) package that will be developed specifically to address those misconceptions. The effectiveness of the CAI package in reducing the incidence of misconceptions will then be measured again by interviews and pencil and paper tests.

INTRODUCTION

Science educators and cognitive psychologists have shown a growing interest in the intuitive ideas of students about natural phenomena prior to, or following exposure to instruction. A large number of studies have shown that many of these ideas (also called misconceptions) are in marked contrast with the scientific conceptions they are expected to learn (Osborne and Wittrock, 1985; Osborne and Cosgrove, 1980).

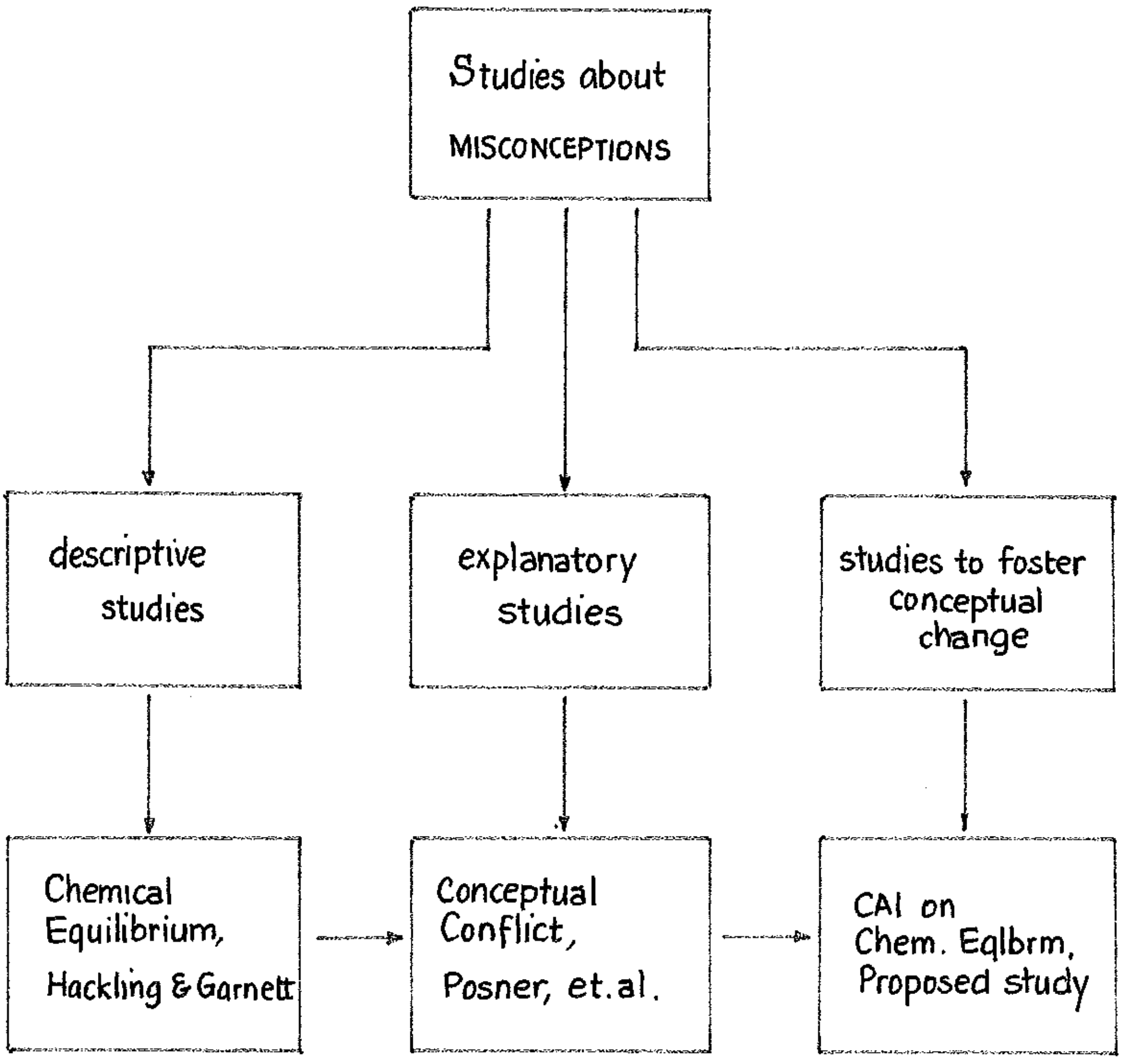
Empirical studies also indicate that misconceptions are quite resistant to change and hinder the acquisition of scientifically correct conceptions (Posner, Strike and Gertzog, 1982). Students can successfully complete science courses while still clinging to misconceptions since they are not revealed by traditional evaluation methods. Further, many students are known to view scientific knowledge as distinct and inapplicable to the realm of everyday experience (Novak, 1988).

Numerous studies have sought to catalogue misconceptions in a variety of science topics. For example, chemical equilibrium has been identified as a topic about which some students have misconceptions (Hackling and Garnett, 1985). It is generally accepted that the unlearning of misconceptions might be the most crucial step in the subsumption of new knowledge. Various theories and models have been developed to foster conceptual change. However, very few studies have sought to test these in experimental settings.

Background to the Study

The literature on misconceptions can be usefully divided into three types: descriptive studies, explanatory studies and studies to foster conceptual change. The first type documents misconceptions in various subject areas. The second type tries to explain the reasons for conceptual stability and change, and the third type uses the theoretical basis of explanatory studies to foster conceptual change. This study is based on the descriptive study of chemical equilibrium of misconceptions by Hackling and Garnett (1985) and the model of conceptual change which advocates the creation of conceptual conflict, initially proposed by Piaget and thereafter refined by Posner et. al. (1982). This model will be used as a theoretical basis for the design and development of the computer-assisted teaching programme. The effectiveness of this model in exchanging misconceptions for scientifically acceptable conceptions has been demonstrated in studies which attempted to foster conceptual change (Zietsman and Hewson, 1986; Fetherstonhaugh, 1988).

This study also draws from the descriptive research on misconceptions about chemical equilibrium especially Hackling and Garnett (1985). Hackling and Garnett identified a total of fourteen misconceptions about chemical equilibrium. They also specified the concepts and propositions deemed to be necessary to understand the topic. The propositions will be used in the remedial sequences of



Relationship between proposed study and previous studies

Figure 1

the programme. Further, the interview instruments and pencil and paper tests developed by Hackling and Garnett will be used in the misconception identification phases of the research.

The conceptual framework for the design of this study is also drawn from previous research to foster conceptual change. Figure 1 shows the place of this study within the existing literature.

The Research Problem

Misconceptions of students about science topics have been a major concern of educators in view of the difficulties they pose in learning.

In the area of chemistry, misconceptions about chemical equilibrium can be expected to present a hurdle which would hamper acquisition of further chemistry concepts. Several conceptual change strategies have been proposed. However, the educational benefits of this research have not filtered through to the classroom. This is because practical instructional strategies based on conceptual change theories have not been adequately researched and their curriculum implications not fully explored.

Rationale and Significance of the Study

The crucial role misconceptions play in concept learning is now well-established with overwhelming evidence. Many studies still continue to document misconceptions in various science topics. However, very few explanatory studies have been conducted to investigate the nature of conceptual change and stability. Even fewer studies have utilized the results of these investigations in the development of teaching programmes. The proposed research could make a timely contribution to the literature on this area.

Chemical equilibrium is recognized as one of the most difficult topics of Chemistry at school level. Non-traditional instructional strategies for remediating misconceptions about this topic, especially the use of the computer, have yet to be pursued. This study may suggest useful ways of teaching this topic.

Further, as this study evaluates a teaching strategy, it may lead to suggestions for improving the way students are taught, teachers are trained and curriculum materials are produced.

Purpose and Research Questions

The proposed research is undertaken with two main purposes in view. First, to develop a computer-assisted teaching strategy based on a model of conceptual change to challenge the previously identified misconceptions of chemical equilibrium. Second, to determine the effectiveness of the developed strategy in a sample of about thirty Year-12 students who have misconceptions about chemical equilibrium.

A subsidiary purpose of this research is to measure the incidence of misconceptions previously identified in WA students in a sample of students from the Maldives.

More specifically, the study will address the following research questions:

(1) What misconceptions about chemical equilibrium are held by Year 12 chemistry students from the Maldives?

(2) To what extent are misconceptions of chemical equilibrium changed by working through the computer-based instruction programme based on a conceptual change strategy?

In addition this study will also address the following subsidiary research question:

How does the incidence of misconceptions of Maldives' students compare with WA students?

PROPOSED METHODOLOGY

Subjects

The subjects for this study will be drawn from Year 12 students in Maldives studying for the London GCE (O/L) Examinations. All of the students would have received instruction in chemical equilibrium up to the level required by the University of London School Examinations Board (ULSEB). There are very few differences in the syllabuses between WA Examinations Board and ULSEB with regard to chemical equilibrium.

Instruments

Pencil and Paper tests and an interview instrument developed by Hackling and Garnett (1985) will be used in pretest and posttest phases of the research. The interview instrument consists of a series of probing questions. The responses of students to the interview will be recorded, then transcribed and later coded for analysis.

CAI Package

The CAI package will be developed for each significant misconception as follows:

(1) The nature of the misconception will be analyzed in order to identify the chemical propositions misunderstood by the students.

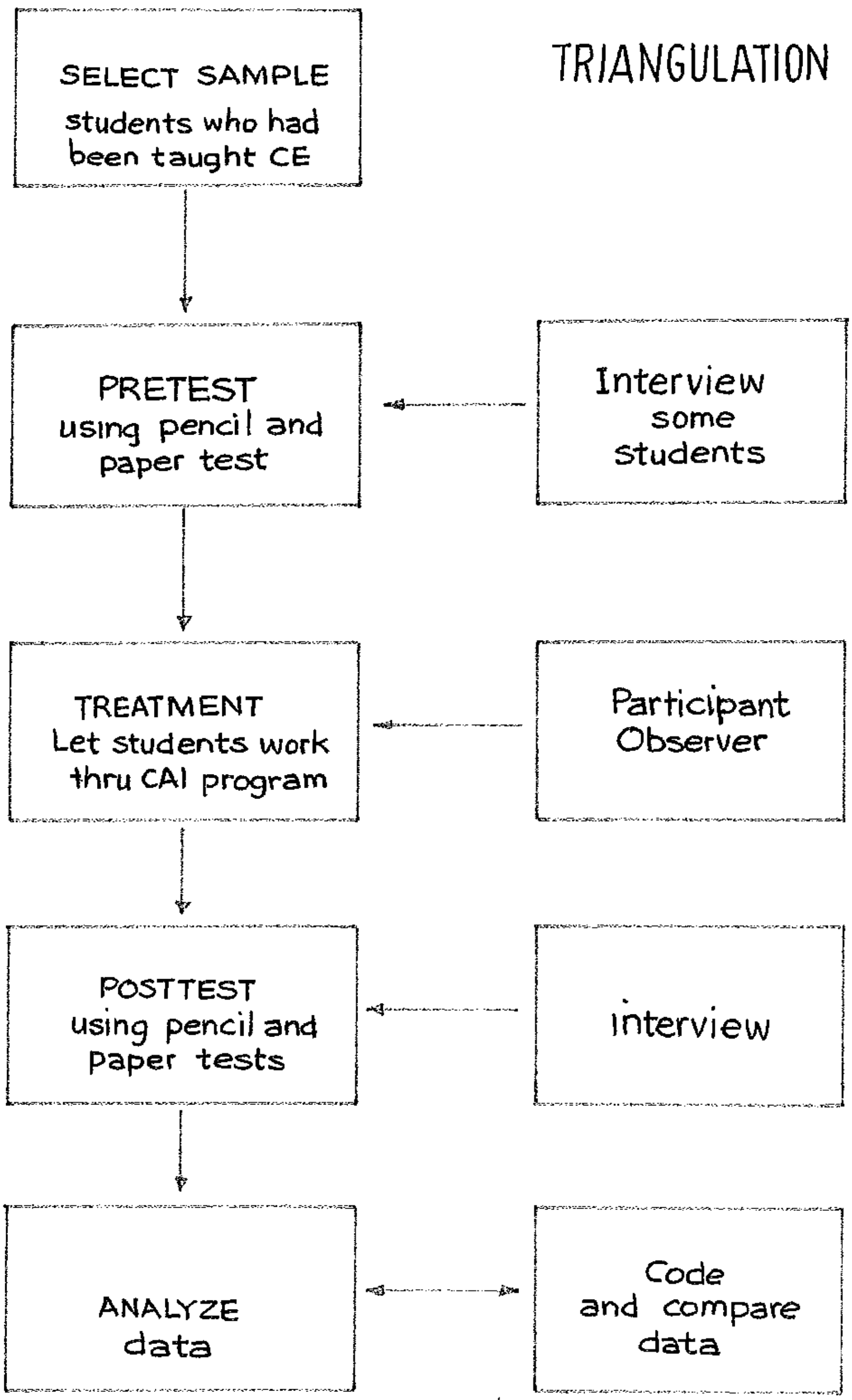
(2) A computer program will be designed to present a situation in which the proposition can be graphically simulated. The student would be able to manipulate key variables controlling the reaction.

(3) A situation will be presented in which the misconception cannot be used as explanation.

(4) A different situation to (3) will be shown to demonstrate the plausibility of the correct preposition.

Procedure

A group of thirty Grade-12 students will be exposed to traditional instruction in chemical equilibrium and then tested to identify the prevalence of misconceptions. Following this, students will work through the computer-assisted conceptual change materials in an attempt to change their misconceptions. The students will then be tested again to determine if the incidence of misconceptions has been reduced. The data from these pencil and paper tests will be supplemented by interview data gathered from a subset of the sample. Interviews will be conducted prior to initial instruction, after initial instruction and after the exposure to the conceptual change materials. The procedure is diagrammatically shown in figure 2. The investigator will act as an observer of both phases of instruction and will conduct the interviews. All instruction will be conducted by the regular class teacher.



Proposed Procedure

Figure 2

The experimental design of this study does not involve a control group. This decision was made on the following grounds. First. numerous studies (Osborne and Wittrock, 1985) have shown that traditional instruction does not create conceptual change. Second, maturation has little effect on misconceptions. Novak (1988) followed a group of students for ten years and found that there was little change in misconceptions despite maturation and teaching. Further, the students are unlikely to undertake new learning experiences during the experimental period. In addition, the study follows a mix of naturalistic and positivist research paradigms. Therefore, its was decided that a control group could not significantly contribute to the validity of the outcome of the experiment.

Data Analysis

The data obtained from the pretest and posttest will be analyzed using a statistical package to determine the effectiveness of the CAI package in lowering the level of misconceptions. The pencil and paper tests will provide quantitative data about the extent of change whereas the interview data will provide qualitative data about the nature of conceptual changes.

LITERATURE REVIEW

Introduction

Since the late 1970s, there has been a growing interest among researchers about students' misconceptions of natural phenomena. Investigators have shown that these misconceptions are different from scientific conceptions. Further, they are found to be resistant to change and impede acquisition of scientific conceptions (Cosgrove and Osborne, 1985).

A large number of studies have attempted to catalogue these misconceptions in various subject areas. Investigators have examined the nature of misconceptions, their acquisition, persistence, and change (Posner, Strike, Hewson & Gertzog, 1982; Osborne and Wittrock, 1985; Gilbert and Watts, 1983).

This review first presents the definitions of key terms used, and discusses the origin and persistence of misconceptions. It then surveys different learning theories which deal with misconceptions. Descriptive studies of misconceptions about chemical equilibrium are then reviewed. This is followed by a discussion of various strategies for bringing about conceptual change and their implications for instruction. Finally a discussion of the use of computer-assisted teaching methods for conceptual change completes this review.

Definition of Terms

Despite the plethora of research efforts in the area, the lack of coherence among studies led Gilbert and Watts (1983) to comment that research was in a 'pre-paradigmatic' phase. Hashweh (1988) concurred with Gilbert and Watts. One of the reasons for the lack of an established paradigm of research is the confusion regarding the basic ideas: 'concept' and 'misconception'. It is, therefore, essential at the beginning to define the meanings attached to these key terms.

Concepts

Traditionally, concepts were believed to be 'universal statements' acquired from inductive generalizations of a large number of diverse events observed with an unprejudiced mind and using unprejudiced sense organs (Gilbert and Watts, 1983). New views of concepts take note of the fact that they may be subjective and constructed from the restricted perspective of personal experience.

For example, Novak (1988) defined concept as "a perceived regularity in events or objects designated by a label". Pines and Leith (1981) defined a concept as "a locus of meaning - sort of summary of all the propositional relationships in which that concept participates." They argued that human beings create concepts by slicing the world into objects and events that bear similarity. Concepts that are similar are then further categorized creating hierarchical conceptual structures.

The following definition of concept by White (1988) is broad and general enough to appeal to a wide audience and contains the essence of most previous definitions:

> A concept is the collection of memory elements that are associated with a label and the pattern of their links. (p. 24)

Preconceptions,

Misconceptions and Alternative Conceptions

Confusion about terminology is not restricted to the term 'concepts' alone. A generally acceptable term to describe existing concepts that differ from accepted scientific knowledge has been a matter of contention for many years. They have been variously called 'preconceptions', 'naive ideas' and more generally 'misconceptions'. However, several researchers (Pines and Leith, 1981) contended that student misconceptions are well-established, empirically verified and meaningful to the learners, hence 'misconceptions' is an inappropriate term to describe these. Further, in many cases the concepts are complex and contain multiple links to other concepts within the cognitive structure. Therefore, they suggested the term 'alternative frameworks'.

However, Abimbola (1988), after consideration of the epistemological roots of various terms that have been used to describe student misconceptions, concluded that 'alternative frameworks' was an improper term and suggested 'alternative conceptions' which he argued is more appropriate, applicable and inclusive. Despite the fact that the suggestion makes good sense, researchers have continued to use the term 'misconceptions'. In keeping with the tradition, in this review, 'misconceptions' will be used throughout and should be taken as synonymous with 'alternative conceptions'.

The Nature of Misconceptions in Science

How misconceptions arise

A number of studies has shown that student misconceptions about scientific topics are extraordinarily similar (Stead and Osborne, 1980; Fetherstonhaugh, Happs and Treagust, 1987).

The uniformity of the misconceptions suggests that well-defined causes must be responsible for their formation. Gilbert, Osborne and Fensham (1982) suggested four underlying reasons for the origin of misconceptions. First, many young children do not interpret natural phenomena in impersonal objective ways. Second, for a number of children, what is not observable does not exist. Third, children tend to endow objects with human qualities. Finally children think of abstract ideas such as momentum and velocity as physical entities. These views lead to a perspective which is markedly different from the scientists' and a corresponding variation in the interpretation of reality.

Misconceptions are also derived from everyday use of language (Eylon and Linn, 1988). They can also arise from the incorrect transfer of existing knowledge to explain a new phenomena. Other possible sources of misconceptions would include teachers and textbooks (Cho, Kohle and Nordlond, 1985). Both could reinforce or create certain misconceptions by failing to discuss the concepts correctly.

Learning theories dealing with misconceptions

One theory of learning that takes into account the influence of prior knowledge as a key variable affecting subsequent concept acquisition is broadly termed constructivism. The constructivist perspective has its roots in the interpretive tradition in the social sciences which stressed the importance of personal experience in understanding actions.

According to Novak (1988) the first comprehensive effort to present a theory of learning that dealt with the role of meaning was David Ausubel's (1963) *The Psychology of Meaningful Verbal Learning.* In the epigraph to his 1968 book, *Educational Psychology: A Cognitive View,* he stated,

> If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

Inspired by Ausubel's theoretical work and dissatisfied with existing theories, Novak (1988) suggested several important principles of learning. He described eight of these principles some of which are controversial. The more widely acceptable principles are outlined below:

(1) Concepts are learned early in life. It is an innate ability of human beings to perceive regularities in events or objects and to use symbols to encode these regularities. By age 30 months, children have several hundred concepts.

(2) Misconceptions are learned early and are persistent. The same process responsible for the formation of concepts early in life cause misconceptions. These misconceptions are not easily modified.

(3) Prior knowledge influences subsequent learning. In particular, misconceptions hinder the acquisition of new concepts.

(4) Information processing capacity of the brain is limited. In particular short-term memory can process between seven and nine independent chunks of information.

A large body of research evidence exists in support of most of these principles (Osborne and Wittrock, 1983; 1985). Osborne and Wittrock (1983) proposed the Generative Learning Model consistent with the research findings. According to these researchers the Generative Learning Model is central to the constructive perspective. In their own words,

> The generative learning model is concerned with the influence of existing ideas on what sensory input is *selected* and given *attention*, the links that are *generated* between the stimuli and aspects of memory store, the *construction* of meanings from sensory input and information retrieved from long-term memory, and finally the *evaluation* and possible *subsumption* of constructed meanings.
> (Osborne and Wittrock, 1985:64)

Persistence of Misconceptions

The persistence of misconceptions have been attributed to well-differentiated cognitive schemata. The existence of multiple links to different concepts within this cognitive schemata ensures that misconceptions are inextricably connected to well-known concepts. Thus the extinction of a misconception should involve severing the links between it and other myriad accepted concepts. Hence, unlearning a misconception entails a major reorganization of the cognitive schemata, which represents a difficult cognitive task (Hashweh, 1986).

Other factors which contribute to the persistence of misconceptions include cultural beliefs and the tenacity of common-sense epistemology. Many cultures still nurture common-sense epistemology because it is adequate for explaining most everyday experiences (Gilbert, Osborne and Fensham, 1982).

Misconceptions about Chemical Equilibrium

The topic of chemical equilibrium has been recognized as one of the most difficult topics in school chemistry (Finley, Stewart and Yarrock, 1982). This is reflected in the number of studies undertaken to comprehend learning difficulties and misconceptions about the topic (Driscoll, 1960; Wheeler and Kass, 1978; Hackling and Garnett, 1985).

As far back as 1960, Driscoll noted five misconceptions believed to be common within the area of chemical equilibrium. He argued that wrong and ambiguous courseware was a primary cause for the origin of these misconceptions.

Based on the work of Driscoll, Wheeler and Kass (1978) conjectured the prevalence of certain misconceptions and tested their presence. The learning difficulties associated with misconceptions are: (a) the inability to distinguish between the concepts of mass and concentration, and between extent and rate, (b) uncertainty as to whether the equilibrium constant is in fact a constant, (c) misuse of Le Chatelier's principle, (d) inability to appreciate that certain substances display a fixed or constant concentration in certain chemical reactions, and (e) inability to consider all possible factors affecting the equilibrium condition of a chemical system.

Hackling and Garnett (1985) conducted a descriptive study about chemical equilibrium using interviews. The most significant misconceptions identified in this study are summarized below:

(1) The rate of forward reaction increases with time from mixing of the reactants until equilibrium is reached.

(2) There is a simple arithmetical relationship between the concentrations of reactants and products at equilibrium.

(3) When a system is at equilibrium and a change is made to the conditions, the rate of the favoured reaction increases but the rate of the other reaction decreases.

Some of these misconceptions were confirmed and new ones identified in a study by Camacho and Good (1989). This study also revealed that many students do not understand the fact that, in terms of energy content, all reactions are either endothermic or exothermic. The nature of equilibrium constant and the factors affecting it were, again, found to be generally misunderstood.

Conceptual Change

Because misconceptions are highly resistant to change, they are likely to persist into adulthood unless successful intervention strategies occur.

Based on the work of Piaget and Kuhn, Posner et. al. (1982) suggested that there are two distinguishable phases of conceptual change. In the first phase students use existing concepts to deal with new phenomena. The second phase, called accommodation, involves the replacement or reorganization of students' preconceptions when accumulated experiences cannot be adequately explained by existing conceptions. Both phases are believed to occur against the background of learner's current concepts called *conceptual ecology*.

According to Posner, et. al. (1982) four important conditions must be fulfilled before accommodation could occur.

(1) There must be dissatisfaction with existing conception as a result of an accumulated store of unsolved puzzles and anomalies;

(2) A new conception must be intelligible to the student;

(3) A new conception must appear initially plausible i.e. it must be able to solve problems and be consistent with existing knowledge; and

(4) A new conception should lead to new insights and discoveries i.e., it should be fruitful.

Hashweh (1986) proposed a model of conceptual change which stressed the conflict between misconception and scientific conception within the cognitive structure itself. Most researchers have emphasized the conflict between the misconception and a new phenomenon and ignored the internal conflict between the new and old conceptions.

Hashweh argued that misconceptions are derived from experience because the student ignores the extent of the application of the principle. Scientific ingenuity often lies in generalizing simple concepts. According to him, it is the provision of synthesizing information that shows the relationship between the limited case and the general case that is important in inducing conceptual change.

Instruction for Conceptual Change

There is remarkable similarity among the suggested for conceptual change by different researchers (Cosgrove and Osborne, 1985; Osborne and Wittrock, 1985; Driver, 1986; Hewson and Hewson, 1988). The following summarized list, based on Van Hise (1988) is representative:

1. Provide opportunities to make student ideas explicit and give them opportunities to test those ideas.

2. Confront them with situations where their misconceptions cannot be used as explanation, and let them become aware of the conflict.

3. Help them accommodate the new conception by providing opportunities to test them and experience their fruitfulness.

A number of methods have been suggested that enable students to become aware of their misconceptions notably debates, discussions. The technique of 'concept-mapping' have also been suggested. Hewson (1981) suggested delineation of the misconceptions in greater detail to facilitate appreciation of their shortcomings.

Students can also be encouraged to evaluate the constructed meaning against their experiences and real-life situations.
Very few studies have been done to ascertain the effectiveness of these strategies. Fetherstonhaugh (1988) developed a set of teaching modules about light to specifically address previously identified misconceptions. He reported a lowering of the number of misconceptions following its use.

Use of Computers in Conceptual Change Instruction

Several researchers have advocated the use of computers in conceptual change instruction (Reif, 1987; Zietsman and Hewson, 1986). The unique capabilities of computers can be exploited to implement instructional strategies impossible with other teaching methods. For example the graphics capabilities of computers can be used to present meaningful symbolic representations, including dynamic representations of time-dependent processes. Normally unobservable events such as the motion of molecules in solutions can be visually represented in animated colourful displays. Computers can easily store and redisplay past work on cognitive tasks thus enabling the students to diagnose and correct their own errors and misconceptions. Further, computers can provide a supportive environment where students can construct and explore new concepts while providing proper guidance and help at the right time by merely pressing a button.

Zietsman and Hewson (1986) used a program designed in accordance with a model of conceptual change to diagnose and remediate a misconception about velocity. Results indicated that computer simulations are credible representations of reality and the programme produced significant conceptual change in students holding the misconception.

Summary

Research conducted mostly in the past two decades have shown that students' misconceptions play a major role in science concept learning. Misconceptions arise from personal experience and are resistant to change. Several strategies for changing these misconceptions have been suggested most notably the creation of conceptual conflict.

The topic of chemical equilibrium has been identified as presenting many learning difficulties including the prevalence of misconceptions. Computers can play a significant role in bringing about conceptual change by providing meaningful simulations, judicious guidance and immediate feedback.

TIME TABLE FOR COMPLETING THE DISSERTATION

SCHEDULE OF ACTIVITIES FOR THE PROPOSED STUDY											
Activities	**Month of the Year**										Comments
	FB	MA	AP	MA	JU	JU	AU	SE	OC	NO	
Proposal Preparation	##	##	##								
Literature Review	##	##	##	##							
CAI Development				##	##	##					
Instrument Development				##	##	##					
Seminar				##							
Data Collection						##	##				
Data Analysis						##	##	##			
First Draft							##	##	##		
Final Submission										##	

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Mr Hassan Hameed
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Dear Hassan,

My purpose in writing is to congratulate you on a first rate graduate seminar presentation. I was impressed by both your method of presentation as well as the content of your proposed study. Our department has become better because of your involvement and contribution.

May I wish you well in your research. I look forward to reading your final dissertation. I believe it will reflect well on you and this department.

Regards,

Denis Goodrum

Dr Denis Goodrum
Head
Department of Science Education

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