A COMPARISON OF THE EFFECTS OF INQUIRY AND EXPOSITORY TEACHING APPROACHES ON PUPIL UNDERSTANDING AND ATTITUDE TOWARDS BIOLOGY

Kevin André Frisby

Research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science.

Johannesburg, December 1996.

K.A. FRISBY
19 December 1996

ABSTRACT

This quantitative study examined the differential effectiveness of inquiry and expository methods of instruction in terms of pupils' understanding of the human circulatory system and pupils' attitudes towards biology as a subject at school. The sample used in the study consisted of 64 Standard Eight Biology pupils from a Pretoria high school. The "inquiry group" comprised 35 pupils and the "expository group" 29 pupils.

The research procedure included the development of an inquiry "teaching package" dealing with the human circulatory system, designing a *Test of Understanding* and selecting an appropriate *Attitude Towards School Biology Test*. The "package" and the testing instruments were pilot tested before being used in the main study.

Two research designs were used in this study. To compare the levels of pupils' understanding of the inquiry and expository groups a Posttest-only with Nonequivalent groups was used, whilst an Untreated Control Group Design with Pretest and Posttest was used for the comparison of pupils' attitudes towards biology as a school subject.

An Analysis of Covariance (ANCOVA) revealed no significant differences in pupils' understanding of the circulatory system between the inquiry and expository groups. There were also no significant differences between the two groups in terms of pupils' understanding when comparing Higher Grade and Standard Grade pupils separately.

ANCOVA revealed no significant differences between the inquiry and expository groups in pupils' attitudes towards biology as a school subject. A Chi-square test revealed that a significantly larger number of pupils in the inquiry group responded favourably to the statement "Biology is fascinating and fun". A Chi-square test , however, revealed no significant differences between the two groups in terms of responses to the statements "During Biology class, I usually am interested", and "Biology is interesting to me and I enjoy it".

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the following people:

- Dr Martie Sanders, for her guidance as supervisor as well as her support and interest in this study

- My loving wife, S[illegible]lla, for her encouragement, moral support, patience and hours of word processing my rough notes

- My son, Arnold, for his patience

- My parents for their encouragement, particularly my mother, Charmaine, who sadly passed away during the course of this study

- Mrs Di Hartley and Dr Neil Sparrow, for their enthusiastic participation in the pilot study and the main study respectively.

My thanks to God for giving me the strength to complete this study amidst difficult circumstances.

TABLE OF CONTENTS

Chapter 1 - Context of the study

Chapter 2 - A review of the literature on inquiry learning

Chapter 3 - Research methods and collection of data

Chapter 4 - Analysis and Discussion of Results

Chapter 5 - Discussion and Conclusion

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1 - Context of the study

The effect of an inquiry-based curriculum on students' learning and attitudes has been investigated by several researchers. Various studies have shown a possible link between an inquiry approach and improvements in achievement, understanding, attitudes to science and improved skills (Shymansky et al., 1990). Similar findings were made by Selim and Shrigley (1983) regarding attitude and achievement, skills and attitude by Brodderman (1985), and on reasoning, achievement and attitude by Hall and McCurdy (1990). However, whilst some studies have reported positive outcomes, others claim no effect at all (Crocker et al., 1976).

In this study an inquiry teaching package dealing with the human circulatory system was developed by the researcher in order to evaluate the effectiveness of an inquiry approach on pupils' understanding of biological concepts as well as their attitudes towards biology as a subject at school. The inquiry package was taught to an experimental group of 35 Standard Eight Biology pupils. Their performance on a theory test of understanding as well as their attitudes towards biology were compared to those of a control group of 29 pupils to whom the same tests were administered. The control group was taught the same content using an expository approach. The theory test of understanding was developed by the researcher whilst an exisisting attitude towards biology test developed by an experienced researcher was used.

1.1 STATEMENT OF THE PROBLEMS

Two problems are of interest in this study, namely, the apparent lack of understanding of biological concepts as well as unfavourable attitudes towards the sciences among secondary school pupils in South Africa.

1.1.1 Understanding

It has been my experience from teaching senior biology in South African government secondary schools for the past eight years that many of my biology pupils, when required to apply learned knowledge to new situations, are unable to do so. Although many pupils do not understand, (comprehend) the concepts and as a result cannot apply them, they may still pass and could even achieve good results by answering the factual recall questions correctly. This suggests that many pupils are rote-learning for the examinations. This achievement raises concerns (well beyond the scope of this study) about the questions used in the examinations at those schools, and possibly elsewhere in the country.

A lack of understanding of scientific concepts among high school pupils does not seem to be restricted to this country. Driver and Bell (1986, 433) suggest that *"there is concern among science teachers in many countries that perhaps the majority of secondary students neither understand, nor see much point in the conceptually based science they are taught at school."*

1.1.2 Attitudes

In my teaching I have encountered many pupils that have unfavourable attitudes towards biology (one of the sciences taught in South African schools) as a subject. Many pupils have indicated to me that they dislike memorising large quantities of "facts" and "diagrams" and that they don't do enough "investigating" themselves.

Gogolin and Swartz (1992) contend that for many students, learning science involves negative feelings and attitudes which discourage further exposure to any scientific enquiry. Mason and Kahle (1988) suggest that some of the negative feelings held by students towards science, or the study of science, may be attributed to the teaching of science rather than the nature of the subject itself. It is the opinion of Germann (1988) that scientific endeavours should not be viewed as secretive, frightening or impossible. Instead, science should elicit feelings of excitement, wonder, curiosity and challenge. It would be interesting to see if using an inquiry approach to teaching improves pupils' attitudes towards biology.

1.2 PURPOSE OF THE STUDY

Research on inquiry learning suggests the possibility of an increase in pupil understanding when learning extends beyond the verbal level whereby students merely rote-learn factual knowledge without necessarily understanding the concepts involved (Carin and Sund, 1980). Wellington (1981) argues that inquiry methods of teaching could also improve pupils' attitudes towards and appreciation of science, which impinges on the "affective domain" of Blooms' Taxonomy.

Understanding and attitude are regarded as two important domains of science education (McCormack and Yager, 1989). In this regard Yager and Penick (1984, 143) argue that "*if we are truly to influence and improve science education, we must place students at the forefront of our thinking and we must consider the affective as well as cognitive domains*". Wareing (1990) suggests that in a healthy curriculum there should be a simultaneous interplay between cognition and the affective domain. Feelings and facts should be joined together in a mutual alliance. It is therefore important to develop instructional strategies that improve affective outcomes as well as achievement outcomes (Gogolin and Swartz, 1992).

To date in South Africa little research has been published on inquiry teaching, particularly in relation to pupil understanding and attitudes towards biology as a school subject. It is suggested that this study could make a contribution to the ongoing debate on problems and issues in science education, particularly with respect to inquiry learning.

The specific aims of the study are to design an **inquiry-orientated** "teaching package" dealing with the human circulatory system for use by Standard 8 Biology teachers and to evaluate its comparative effectiveness against a more traditional **expository approach** regarding:

- pupils' <u>understanding</u> of the circulatory system, and
- pupils' <u>attitudes towards biology</u> as a school subject.

1.3 DEFINITIONS FOR THE PURPOSE OF THIS STUDY

From the review of the literature it is apparent that both "inquiry" and "attitude" are problematic terms, as different authors use them to mean different things. This may be a reason for the inconsistency of research findings on the effects of inquiry learning. Wilson (1974) states that inquiry is a process model of instruction which is often confused with open-ended, undirected activity which is assumed to simulate scientific activity. Inquiry learning is not restricted to the act of finding out something that was previously unknown, but rather includes all forms of obtaining knowledge for oneself by the use of one's own mind (Pugliese, 1973). Tamir (1983) emphasises the importance of differentiating between the teaching of science "as inquiry" and teaching science "by inquiry". Teaching and learning as inquiry opens opportunities of getting first-hand experience in doing science, and in addition develops inquiry skills, such as the ability to identify and define a problem, to formulate an hypothesis, to design an experiment, and to collect, analyse, and interpret data. The teaching of science by inquiry, on the other hand, in addition to transmitting concepts, principles, and facts, has the responsibility of conveying a realistic image of science and its nature (Tamir, 1983). Teaching science by inquiry allows students to use all forms of obtaining knowledge for themselves in accordance with the view expressed by Pugliese (1973). Tamir (1983) contends that teaching science by inquiry should be given first priority as the main objective of science teaching.

In this study the following definitions will be used:

Inquiry teaching: This will be defined as an approach which allows pupils, under the guidance of the teacher, to discover for themselves information new to them by active participation (taken to mean acting on material objects physically and mentally and "doing" things with social collaboration). Lessons begin with practical work (i.e. experiments, dissections, comprehension exercises, manipulating models, viewing biostrips etc.) guided largely by open-ended worksheets, and end with pupil-pupil and pupil-teacher questions and discussions to consolidate concepts to be learnt.

Expository teaching: This is an approach to teaching by which all the relevant information is given to the pupils by the teacher. A large proportion of teaching time is taken up by facts being "exposed" by step-by-step explanation on the part of the teacher, usually by a conventional lecture approach. Practical work is used mainly to verify information already taught. Generally there is limited pupil-pupil interaction as well as a lack of pupil-initiated discussions.

Understanding: This occurs when concepts to be learned are consciously related to relevant concepts which have been acquired previously, and integrated into the learners' conceptual framework in a meaningful way. Learnt concepts can then be applied in different but similar contexts to solve unseen (unknown) problems (Head, 1982).

Attitude: Despite many different and more recent definitions, Allport's definition will be used in this study. "An attitude is a mental and neural state of readiness organised through experience, exerting a direct or dynamic influence upon an individual's responses to all objects and situations with which it is related" (Allport, 1935, 810).

Attitude to science: Attitude in this sense is seen as a tendency or inclination to respond, in an unfavourable or favourable manner to science (Wareing, 1990). In this study pupils' attitudes towards biology as a subject at school is investigated.

1.4 RESEARCH QUESTIONS

An attempt is made in this study to answer the following two questions:

1. Do Standard 8 Biology pupils taught by an inquiry teaching approach have a better understanding of the circulatory system than pupils taught by the traditional expository approach?

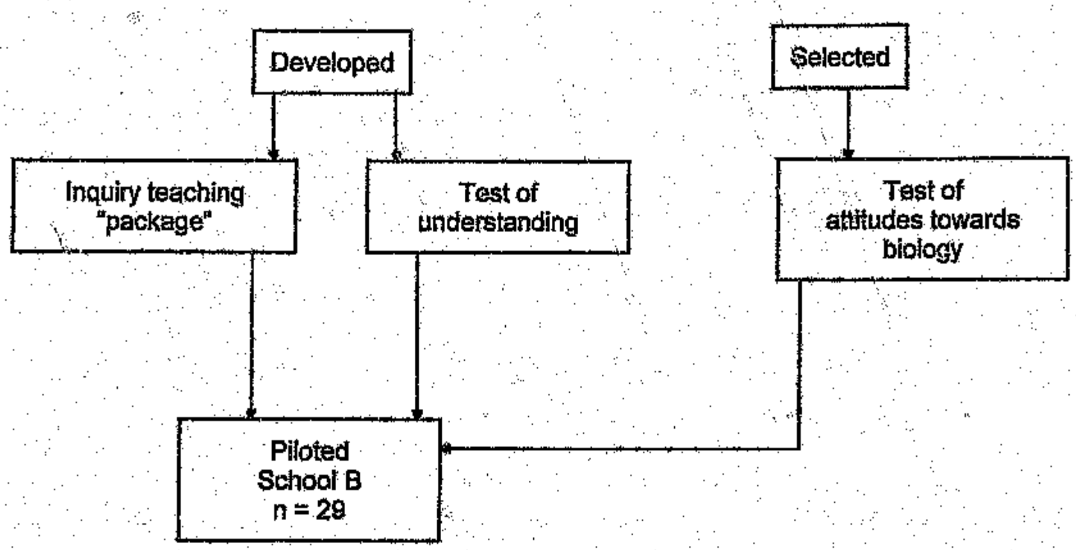
2. Do Standard 8 Biology pupils receiving inquiry-orientated instruction develop more favourable attitudes towards biology as a school subject than do pupils receiving expository instruction?

1.5 PROCEDURES

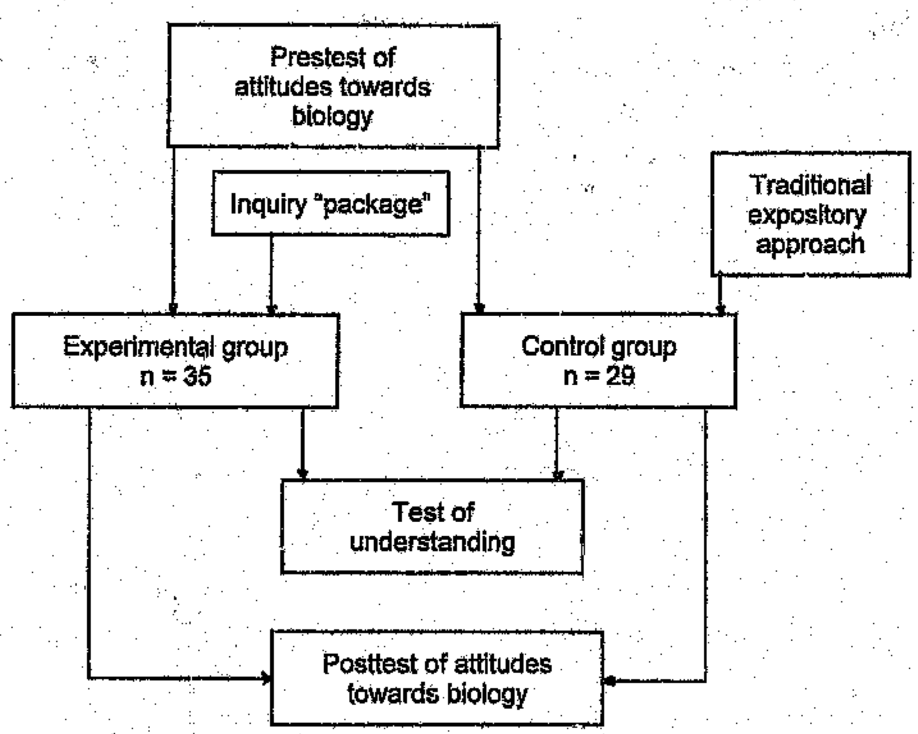
1.5.1 Overview of procedures followed

Procedural details

Phase I



Phase II - main study



1.5.2 Research design

Two research designs are used in this study. For the comparison between the experimental and control groups of pupil understanding a Posttest-only Design with Nonequivalent groups was used (Cook and Campbell, 1979). The sample used was non-randomised and nonequivalent, as the use of two intact classes was all the researcher had access to.

For the comparison between the experimental and control groups of pupils' attitudes towards biology an Untreated Control Group Design with Pretest and Posttest was used (Cook and Campbell, 1979).

1.5.3 Samples

Two Standard 8 Biology classes (n = 64) from a Model C Pretoria High School were used in the study. A Model C school is a state-aided school in which the parents are responsible for financing and coordinating the daily functioning of the school through the governing body and parents association. The state is responsible only for paying the salaries of the teachers at the school. Curricula prescribed by the government education department are followed.

The sample for the pilot study in which the inquiry package as well as the two testing instruments was trialled, comprised 29 Standard 8 Biology pupils from a neighbouring Model C High School. The neighbouring school can be described as very similar in composition and character to the school used in the main study.

1.5.4 Instruments

(i) Test of Understanding (TOU)

A theory test to assess pupil understanding was designed by the researcher. It is important that the test of understanding actually does test understanding so that inferences made on high and low scores on the test regarding understanding are valid. The instrument was pilot-tested to determine whether any problems existed with instructions given, the readability, or the lay-out of the test items.

(ii) **Attitude Towards School Biology Test**

An existing test, the Attitude Toward Science in School Assessment (ATSSA) developed by Paul Germann (1988) of Maine, USA was used. The ATSSA was found to be appropriate within the context of this study as it measures a single dimension of a general attitude towards science, specifically, how students feel towards science as a subject in school. The ATSSA is a Likert-scale instrument with a five-point response scale to items ranging from strongly agree to strongly disagree. In studies done in the United States it has shown consistently Cronbach alpha estimates of reliability greater than 0,95 (Germann, 1988).

For the purpose of this study the word "science" was replaced by the word "biology" in all the items of the test. The name of the test was also changed to the *Attitude Towards School Biology Test.*

1.6 ANALYSIS OF DATA

Means, variance, standard deviation and degrees of freedom were calculated for each of the two classes on posttest scores for both the achievement and the attitude tests. This was required to carry out an analysis of covariance (ANCOVA). ANCOVA enables the adjustment of the posttest mean scores for each group to compensate for the initial differences between the groups. In this study the June exam results of the pupils were used as the covariate to remove extraneous variations from the posttest scores for the test of understanding. In the attitude towards biology component the pretest scores for the same test were used as covariates. Frequency tables and bar charts were used to present the results. Although not originally planned, posttest mean scores for Higher and Standard Grade pupils seperately were also compared and ANCOVA applied. This was done so as to determine whether Higher or Standard Grade pupils may be more or less suited to the inquiry approach, if at all. An item analysis of selected items from both the test of understanding as well as the attitude test was done. These items were selected as the researcher felt that certain items in the test more closely assessed with the aims of inquiry learning than others. The results are presented in contingency tables and a chi-square test procedure was applied. The chi-square test was used to analyse data obtained from the item analysis. The value of chi-square and its level of statistical significance indicates whether or not differences between expected and obtained frequencies are significant or not.

1.7 CONCLUSION

Chapter 1 gives a brief overview of the purpose of the study, the problems investigated and the specific questions posed. Key terms used in the study are defined, the research procedures followed are stated briefly.

In the chapters that follow a review of the relevant literature is given in Chapter 2, while an elaboration of the methods used in the study is provided in Chapter 3. Chapter 4 includes the analysis and discussion [illegible]ata obtained, whilst Chapter 5 includes a critique of the study and summarises the findings.

Chapter 2 - A review of the literature on inquiry learning

The curriculum development movement of the 1960's produced what purported to be a new way of learning at school. Instead of the pupils being the passive recipients of lectures, the new curricula posited a different relationship between teacher and pupil, and a different mode of learning. The new curricula envisaged that the pupils should retrieve information from the range of resources provided by the teacher rather than the teacher being the sole source and importer of knowledge. The pupils, in essence, would become agents for their own education. The acquisition of inquiry skills was thus to be central to the new approach. Mills (1977) contends that inquiry curricula view the process and skills of knowledge acquisition as primary and the product and the knowledge itself as secondary.

This writer supports the view expressed by Mills (1977) that inquiry curricula may produce learning outcomes consistent with the requirements and demands of living in a society which is increasingly being shaped by science and technology. It thus seems important that pupils acquire skills necessary to respond to an ever changing, unpredictable world.

2.1 HISTORICAL REVIEW OF THE DEVELOPMENT OF INQUIRY LEARNING

2.1.1 Socrates

According to Wellington (1981) the first advocate of inquiry learning was probably Socrates (400 BC) with his non-telling approach to learning. Wellington describes how Socrates enabled a mere slave to discover a mathematical theorem for himself without being told anything, but after deducing it himself after being asked a series of questions.

2.1.2 Rousseau

During the eighteenth century, in his book Emile, Rousseau argued for a less intellectualised, more person-centred, more experience-based concept of education (Delaney, 1980). According to Delaney, Rousseau held that education should focus primarily on the uniqueness and worth of the individual child, it should provide him with an environment within which he could develop his own distinctive potential, and it should also provide a setting that would best allow opportunity for learning through experience (Delaney, 1980). Wellington (1981) quotes the now famous Rousseau statement: *"Let him know nothing because you have told him, but because he has learnt it for himself"* (Wellington, 1981, 167).

2.1.3 **Armstrong**

Atkinson and Delament (1977) believe that the rationale for inquiry curricula is best articulated by Henry Armstrong at the turn of the century with his 'heuristic' approaches to science education:

> *Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer - methods which involve their finding out, instead of being merely told about things. It should not be necessary to justify such a policy in education... Discovery and invention are divine prerogatives, in some degree granted to all, meet for daily usage ... it is consequently of importance that we be taught the rules of the game of discovery and learn to play it skilfully. The value of mere knowledge is immensely over-rated, and its possession over-praised and over-rewarded.* (Armstrong, 1898, quoted by Atkinsen and Delament, 1977, 88)

2.1.4 **Dewey**

More recently, John Dewey, the main spokesman for progressive education in the 1930's, advocated that children should "learn by doing", rather than being lectured to (Carin and Sund, 1980). Dewey contended that children would learn better by directing their activities and attention to the actual world. Wellington (1981) refers to Dewey's view that the role of the teacher was not to represent authority, but rather to serve as a guide. The discipline that is to be developed is self-discipline, rather than discipline imposed by an external source. Similarly Delaney (1980) expands on Dewey's belief that the primary task of the teacher was to refine experience. This, Dewey pointed out, means that the child should interact freely with materials, but in such a way that the potential growth value of experience is realised. Free and spontaneous interaction is not likely to lead to socially desirable learning outcomes unless a certain amount of guidance is provided by the teacher (Delaney, 1980). He suggests that according to Dewey's views the teacher must be able to direct the child not towards the view that knowledge of the past is the end of education, but rather to emphasise education's importance as a means (Delaney, 1980).

2.1.5 Other psychologists

Later, in the 1960's, psychologists Jean Piaget and Jerome Bruner were responsible for a sharply increased interest in learning using methods of self-discovery, reiterating earlier calls by Rousseau, Dewey and others (Carin and Sund, 1980). Bruner is quoted by Egelston (1973, 467) as stating:

> "*The discovery method is the best way to develop desirable attitudes towards learning and inquiry, towards the possibility of solving problems on ones own, towards an understanding about the ultimate orderliness of nature and a conviction that order can be discovered.*"

2.2 TERMINOLOGY - THE MEANING OF "INQUIRY"

2.2.1 Importance of precise terminology

Having precise terms for something facilitates its use as it may prevent authors from using particular terms that mean different things to different people. Keegan (1993, 17) makes the following statement in this regard:

> "*How much more professional teachers would be - how much more like physicians, attorneys, and engineers - if they would sharpen their introspection, make reasoned improvements, and pass those improvements on to other teachers by using precisely understood terms.*"

A statement by Postman and Weingartner in 1969 is quoted by Keegan (1993, 17): "*Eventually, the profession will have to get its names straight so that intelligent discussions can go forward.*"

2.2.2 Confusion surrounding the notion of "inquiry"

Many writers have contributed towards an understanding of what inquiry learning is. There are, however, many different views and interpretations. After reviewing four large National Science Foundation-sponsored studies assessing the state of science education in the United States in the late 1970's, Welch et al. (1981) emphasised the confusion over the meaning of inquiry in the classroom. Similarly Crocker et al. (1976) state that there has been a tendency to include under the broad rubric of "teaching by inquiry" a whole range of teaching strategies.

Tamir (1983) provides evidence that the notion of inquiry causes a great deal of confusion among teachers and states that this may well be a reason for many teachers not presenting science as inquiry. As was suggested in Chapter 1, different views on the meaning of inquiry may also be responsible for the equivocal research findings regarding the outcomes of an inquiry approach to teaching and learning.

Many science teachers use the terms "discovery learning" and "inquiry learning" interchangeably. Sund and Trowbridge (1973), however, differentiate the meanings. They see "discovery" as being the mental process of assimilating concepts and principles in the mind (observing, classifying, measuring, predicting, describing and inferring) i.e. a process of learning, while "inquiry" describes the process used by the mature scientists performing relatively sophisticated mental processes, i.e. a process of scientific investigation including:

- asking questions about natural phenomena,
- formulating problems,
- formulating hypothesis,
- designing investigative approaches, including experiments,
- carrying out experiments,
- synthesising knowledge, and
- having certain scientific attitudes such as objectiveness, curiosity, open-mindedness and responsibility.

Keegan (1993) also differentiates between 'discovery' and 'inquiry', but on a different basis. Keegan states that there are many typologies of instructional methods and indicates that a popular dichotomy is whether or not the student is actively exercising his or her volition and imagination, or whether the student is subject to the will and imagination of others. This Keegan dubs as the "discovery versus didactic" dichotomy. However, he offers what he calls "a more sensitive" typology based on the view that the instructional moment is in essence, a stimulus followed by a response. Based on this, Keegan delineates four "kingdoms" of instructional methods based on who generates the stimulus and who generates the response, with the instructional moment.

He believes than when the expert generates both stimulus and response, as in an uninterrupted lecture, the instruction is said to be didactic. When the expert generates the stimulus, and the learner responds, the method is socratic, as in teacher-led discussion. When the learner generates the stimulus - for example, a question - and a book or an expert produces a processed, finished response, then the inquiry method is taking place. And, finally, when the learner generates both stimulus and response, the instructional moment is one of discovery method (Keegan, 1993). Keegan's view is visually represented in the following diagram.

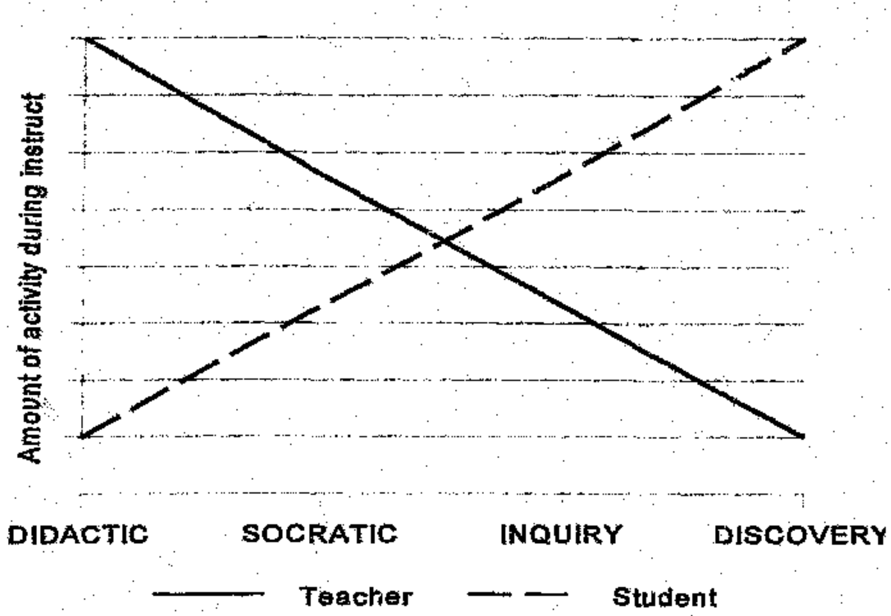


Figure 1: *Hypothetical amount of activity during instruction*
(From Keegan, 1993, 18)

According to Falk (1980), the teacher who makes use of the inquiry approach becomes a guide in helping students uncover information for themselves. The pupil becomes the active performer, the thinker and the experimenter. Falk contends that these are aspects of the inquiry approach which differ from the traditional expository approach to teaching, in which experimentation is used to verify known facts and theory. It is the responsibility of the teacher using the inquiry approach to find ways of guiding the pupils so that they use inquiry skills in order to assimilate biological concepts and find answers to biological problems (Falk, 1980).

Welch et al. (1981) consider inquiry to be a general process by which human beings seek information or understanding. Broadly conceived, Welch views inquiry as a way of thought. Welch et al. (1981) go on to say that scientific inquiry, a subset of general inquiry, is concerned with the natural world and is guided by certain beliefs and assumptions.

Tamir (1983), however, stresses the importance of being more specific. Tamir suggests that a distinction needs to be made between teaching and learning science as inquiry and teaching and learning by inquiry. According to Tamir teaching and learning science as inquiry opens opportunities of getting first-hand experience in doing science and, in addition to this, to developing inquiry skills, such as the abilities to identify and define a problem, to formulate a hypothesis, to design an experiment, and to collect, analyse, and interpret data. Tamir contends that there may be good reasons to suggest that many of the problem-solving assignments and discovery learning exercises supported by the National Science Foundation in the United States in the 1960's (with a learning science as inquiry approach) are beyond the capabilities of many students and teachers. Tamir states that perhaps many students may profit from a more structured presentation. In accordance with this view Carin and Sund (1980) state that they believe in guided discovery, not the laissez-faire, "*children do what you want and you'll learn*" approach. Wilson (1974) states that in an inquiry-based classroom, the learner should be placed in situations where inquiry into new phenomena or explanations is performed with external guidance. The teacher should provide cues to direct the inquiry, and should provide related observations to guide the conceptual experimentation. This more structured approach Tamir (1983) refers to as teaching and learning by inquiry. This approach, in addition to transmitting concepts, principles and facts, has the responsibility of conveying a realistic image of science and its nature. This writer supports the view of Tamir that it is the latter approach i.e. teaching and learning by inquiry that should be given first priority as the objective of science teaching.

2.2.3 **Characteristics of inquiry methods**

Isaac (1993) provides a useful summary of the characteristics of inquiry methods of teaching which in the opinion of this writer seem to be in accordance with the teaching and learning by inquiry suggested by Tamir (1983). They include:

- step-by-step teacher explanation to pupils, limited to a few difficult concepts;
- practical work designed to investigate problems, the answers to which are not already known;
- regular use of experimental data and a range of resource material;
- practical work sheets largely open-ended;
- frequent reference to the tentative nature of science;
- frequent pupil-to-pupil interaction;
- frequent pupil-initiated discussions.

In contrast to this, Isaac (1993) gives a detailed list of the "expository" methods of teaching:

- a large proportion of time taken by the facts, concepts, principles "exposed" by step-by-step explanation on the part of the teacher, by conventional lecture;
- little or no reference to the tentative nature of science;
- questions mainly designed to obtain responses based on the body of information taught;
- practical work designed mainly to verify information already learnt;
- the use of practical work sheets with detailed step-by-step instructions of procedures to be used, precautions to be observed, observations to be made, data to be collected and methods of recording and analysing data;
- limited or no pupil-to-pupil interaction; lack of pupil-initiated discussions.

2.3 REASONS FOR PROPOSING INQUIRY LEARNING

Bruner gives the following four main reasons for using inquiry learning (Carin and Sund, 1980):

- It encourages intellectual development. An individual learns and develops his mind only by using it.
- It creates intrinsic motivation. As a consequence of succeeding at discovery, the student receives a self-satisfying reward.
- It helps with acquiring techniques of discovery. The only way individuals acquire the techniques of discovery is by exposure to discovery.

- It improves memory retention. Something reasoned out yourself stays fresh in your mind, but concepts you were told in a lecture may escape your mind.

Carin and Sund (1980) add some of their own reasons:

- Self-concept development. Only by being involved in learning can one manifest one's potential and gain insights into the "self". Part of the task of becoming a better person is to build one's self-concept. Inquiry learning provides abundant opportunities for this.

- Development of talents. Humans are a collection of hundreds of talents, and academic talent is only one of these. The more freedom one has, the more opportunities there are to develop talents such as creativity, socialisation, organisation etc.

- Increased expectancy levels. Students learn from previous inquiry experiences that they can "think autonomously", and expect to be successful in solving future problems on their own.

- Inquiry methods avoid learning which happens only at the verbal level. The learning of a definition, rule, etc. takes place mainly on a verbal level, without meaning. Inquiry learning predisposes pupils to obtain their own meanings from the environment, preventing learning only at the verbal level.

2.4 MORE-CONTEMPORARY ARGUMENTS FOR SUPPORTING INQUIRY

Inquiry methods bring about an awareness of the nature of science itself (Wellington, 1981). This is recognised as one of the important aims of science education (Crocker and Bartlett, 1976; Welch et al., 1981; and Tamir, 1983). Various writers suggest that teaching and learning by inquiry may be best suited to create an awareness of the methods and processes of science (Falk, 1980; Wellington, 1981; Isaac, 1993). It must be noted, however, that these writers have not made the distinction between teaching science as inquiry and teaching science by inquiry. This writer believes that teaching by inquiry may not necessarily guarantee the development of an awareness of the methods and processes of science.

2.4.1 Inquiry learning may create a greater awareness of the nature of science

The view of Schwab (1964) that science is an "investigative discipline" is supported by Novak's statement on science as: "*... an active field of inquiry moving forward through experimentation based on principles and concepts that are subject to modification.*" (Novak, 1970, 15)

Similarly Welch et al. (1981, 34) state that:

> "*the nature of scientific knowledge is tentative - the product of human efforts - affected by the processes used in its construction and by the social and psychological context in which the inquiry occurs. Scientific knowledge is also affected by assumptions about the natural world, such as causality, noncapriciousness and intelligibility*".

Other writers such as Voss and Brown (1968) refer not only to the products and processes of science, but also to the third component, "the way of life of the scientist", by which is meant the attitude and values required of a scientist when he is engaged in a scientific enterprise.

But why is it so important for students to understand the nature of science? One argument relates to the rapid change at which scientific knowledge is revised. Students who view science as a collection of facts will eventually encounter revised versions and will become confused in the disappearance of the "facts" that they were taught, for they have no basis for understanding the change. In this regard the Biological Sciences Curriculum Study (BSCS) (1963, 42) quote Connerly as saying:

> "*Students are likely to become cynical about scientific enterprise and will certainly regard what they have learnt as of little value ... Also as future citizens they will be ill equipped to follow scientific debates concerning public issues.*"

2.4.2 Inquiry learning is in accordance with contemporary views on the nature of learning

Another contemporary argument for supporting inquiry is the view of how learning itself takes place. In contrast with our common sense view of learning as passive 'absorbing knowledge', current perspectives suggest that learning involves an active process in which each learner is engaged in constructing meanings, whether from text, dialogue or physical experiences (Driver and Bell, 1986). Such an approach is often referred to as the constructivist view of learning.

The constructivist view of learning

For educationists seeking an alternative to the traditional positivist view that learning is the transmission of objective knowledge and that learning is the uncritical absorption of knowledge, the notion that understanding is actively constructed by the learner is a welcome alternative (O'Loughlin, 1992). Wellington (1981) notes that contrasting active learning and passive remembering has long served as the foundation for progressive and child-centred approaches to pedagogy.

Carin and Sund (1980) refer to Piaget's contributions to learning theory and state that "*he has shown humans are not born with faculties, waiting to flower, but rather each person must, through interaction with the environment construct his or her own intellect*".

The essence of a constructivist view of learning according to Johnstone (1986) seems to include that:

- Pupils may come to school with ready-made ideas and explanations for things, which they have gleaned from many sources. Some of these ideas may be seen as being scientifically correct and others not.
- How we learn is conditioned by what we already know. Pre-knowledge which people already possess is of critical importance in their attempts to make sense of new knowledge and experiences.
- Knowledge is not transmitted intact from teacher to learner. There seems to be a need for a learner to reconstruct his own version of the 'new' knowledge, by comparing it with what he already knows and by seeking connections in his existing

corpus on which to hang the new ideas.

Johnstone (1986) notes that two processes namely accommodation and assimilation come into operation and need to be considered. If some new but recognisably familiar idea is presented the learner does not need to accommodate (modify) his body of ideas to be able to assimilate the new idea. Johnstone (1986) goes on to say that in an extreme case the new idea may be so dissimilar to anything that the learner knows that accommodation is impossible. Assimilation (linking ideas) also becomes impossible and the learner will create a new box and memorise the incoming idea, but not be able to link it to his/her existing body of knowledge.

Similarly, Fosnot, a leading advocate of the application of constructivism to teaching according to O'Loughlin (1992, 796), states the four foundational principles of constructivism:

(i) "*knowledge consists of past constructions*
(ii) *constructions come about through accommodation and assimilation*
(iii) *learning as an organic process of invention, rather than a mechanical process of accumulation of knowledge*
(iv) *meaningful learning occurs through reflection and resolution of cognitive conflict and thus serves to negate earlier, incomplete levels of understanding*".

I suggest that inquiry learning may provide adequate opportunities for students to construct their own meanings. Experiences can be provided which challenge pupils' ideas and which conflict with expectations, so provoking students to reconsider their ideas (Driver et al., 1985). It may of course be that students' existing ideas are "correct". Experiences provided will then reinforce these beliefs. In this regard Fosnot is quoted by O'Loughlin (1992, 796) as saying:

> "*A constructivist takes the position that the learner must have experience with hypothesising and predicting, manipulating objects, posing questions, researching answers, imagining, investigating and inventing, in order for a new construction to be developed. From this perspective, the teacher cannot ensure that learners acquire knowledge just by having the teacher dispense it; a learner-centred, active instructional model is mandated. The learner must construct the knowledge, the teacher serves as creative mediator of the process.*"

2.4.3 Inquiry learning results in meaningful learning with understanding

- **Background**

An old Chinese proverb states:

I hear, and I forget
I see, and I remember
I do, and I understand.

Many science educators claim that inquiry approaches to teaching and learning improve students' understanding of scientific concepts (Mulopo and Fowler, 1987; Shymansky et al., 1990). Research findings (see discussion p29-31) have, however, been equivocal.

Howard (1989) contends that "understanding" is a basic goal of science education, but adds that though most would pay lip service to the importance of comprehension, many would be hard pressed to say what the term actually means. Various writers support Howard's view that 'understanding' is a somewhat vague and elusive term (Head, 1982; Summers, 1982) and that there are different views concerning what 'understanding' means.

One school of thought is based on Ausubel's assimilation theory of cognitive learning, elaborated by Novak (1984). The central idea in Ausubel's theory is that of 'meaningful learning', which he defines as "*nonarbitrary, substantive, nonverbation incorporation of new knowledge into cognitive structure*" (Novak, 1984, 608). Cognitive structure is seen as the framework of knowledge stored in our minds that grows and develops from childhood to senescence. Novak states that by "nonarbitory incorporation of knowledge", Ausubel means that the learner must make a conscious effort to relate new knowledge to knowledge he or she already has. Substantive learning occurs when the learner makes a conscious effort to identify the key concepts in new knowledge and to relate these concepts to other concepts. Nonverbation learning is simply the product of nonarbitrary, substantive learning, since the latter active learning processes necessarily alter the meaning of the new knowledge learned (Novak, 1984).

Rote learning, at the opposite pole from meaningful learning, results when students incorporate new information into cognitive structure in an arbitrary, verbatim, unsubstantive way. Ausubel stresses that the rote/meaningful distinction is not a dichotomy but a continuum. Summers (1982), however, suggests that from an Ausubelian viewpoint, meaningful learning can result from reception or discovery methods, as can rote learning. Commenting on discovery learning as a method used during instruction by inquiry Summers (1982, 363) warns that *"discovery methods can be as disastrous as didactic teaching, and inversely both can be equally effective"*. Similarly, Head (1982) argues against some of the claims made for discovery learning in the 1960's and early seventies which tended to suggest that all discovery-type exercises must inevitably produce meaningful learning.

- **Different perspectives of 'understanding'**

One of the aims of the current study is to investigate the influence of inquiry learning on pupil understanding. It is therefore necessary to investigate the meaning of the term. Howard (1989) describes three different views concerning what 'understanding' means. One everyday view is that to understand something is to 'see' it, by being able to visualise it. Howard contends that it is no coincidence that studies suggest highly productive theoretical physicists have excellent visual imagery, Einstein being one prominent example. Another view would have understanding something as being the ability to construct a useful mathematical model of it. Physicists or economists might be quite happy that they understand some aspects of nature or economy when they have a set of equations that quite adequately describes it (Howard, 1989). The third view described by Howard is in line with Ausubel's theory of cognitive learning. By this approach, to understand something is to know and to find [or to construct] a plausible schema which allows one to assimilate it to what one already knows.

Taking a different approach, Hitchcock (1993) lists what students should be able to do if they understand a concept:

- define the concept in words,
- recognise instances of the concept,
- distinguish between instances and non-instances, and
- solve problems involving the concept.

Hitchcock refers to a warning from Osborne and Gilbert that a student may be able to define a concept and yet have little or no understanding of it.

Similar to Hitchcock, Gould (1983, 359) has suggested the following as at least some of the things students can do when they understand something:

- state it in their own words,
- give some examples of it,
- recognise it in various forms and situations,
- see connections between it and other facts or ideas,
- make use of it in various ways,
- predict some of its consequences, and
- state its opposite.

Gould emphasises that if we wish to encourage meaningful learning then pupils do not just need to recall facts but they also need to use them. Our aim in lesson planning, according to Gould (1983), should be to create situations in which the pupil has to actively confront the ideas being presented, and he suggests that a 'guided discovery' approach may be appropriate in this regard.

Gould goes on to list seven kinds of tasks (which may be catered for in an inquiry approach) we can use to help the pupils explore their grasp of concepts. Pupils must:

- reorganise information and present it in a different way,
- use their theoretical knowledge to interpret practical observations,
- use their theoretical knowledge to interpret some of their own experimental results,
- make predictions and design and carry out experiments to test them,
- use what they have learnt in a simulation or 'game' activity, and

- identify and correct the errors in a written account.

Commenting on the theoretical assumptions which underlie research on learning, Fisher and Lipson (1986) state that understanding lies in the extent to which one's internal mental models successfully predict and explain events in the external 'real' world. They also remind us, however, that understanding is achieved by successive approximations, and all understanding is necessarily incomplete and imperfect.

2.4.4 Inquiry learning results in the development of positive attitudes

Leading educators note that science curricula around the world indicate a need and expectation of development of positive attitudes in students by listing attitudinal objectives high on the list of the main goals of science education (Hurd, 1978; Anderson, 1983 and McCormack and Yager, 1989). Johnson et al. (1974) contend that the inquiry curricula of the 60's and 70's were designed to shift the teaching emphasis from repeatable knowledge (what students can say afterwards) as the primary focus in the classroom to a focus on what the students are doing cognitively (the mental operations involved) and how students feel about it (their attitudes towards science). Wellington (1981) argues that discovery methods are held to be the only ones which impinge on the 'affective domain' of Bloom's Taxonomy. Such instructional methods, he feels, could improve pupils' attitudes towards and appreciation of science.

Importance of attitude

Wareing (1990) contends that the value of affective study must not be limited by results of investigations involving relationships of attitudes to other variables. Rather, attitudes require further examination quite simply because of their intrinsic merit. In this regard Wareing (1990) refers to Goldstein's view that essential humanity is evidenced in our attitudinal capacity, and to the views of Gennaro and Glen, that affective outcomes, in and of themselves, are desirable ends and constitute a major component of scientific literacy.

Perhaps greater emphasis should be placed on the development of positive attitudes to science in view of reports of dropping enrollments in high school and tertiary science courses (Gallagher and Yager, 1980; Gogolin and Swartz, 1992). In a study in the USA, Yager and Penick (1984) found positive attitudes towards science in elementary school but a decline in junior high and high school, resulting in young adults who do not feel positive about their school science experience. In South Africa, as far back as 1981, the Human Sciences Research Council in a report on the state of science education stated that:

> *"The fact that the RSA is the most powerful industrial country in Africa - and one of the countries with the biggest industrial potential in the world - is not reflected in the number of scientists produced by the present educational system. One of the reasons for this is that the present syllabuses do not help project a positive image of science and scientists. At the moment the syllabuses are too content-orientated while the real substance of science - discovery, solving problems, participating in science-as-a-process - enjoys too little attention."* (HSRC, 1981, 49).

Criticism of research into attitudes

Many researchers have criticised research into attitudes in science education. First, the construct of "attitude" has been vague, inconsistent, and ambiguous. Second, research has often been conducted without a theoretical model of the relationship of attitude with other variables. Third, the attitude instruments themselves are judged to be immature and inadequate (Munby, 1983; Germann, 1988, Wareing, 1990 and Gogolin and Swartz, 1992).

The current study investigates the influence of learning by inquiry on pupils' attitudes towards biology (as one of the sciences taught at school). It is thus appropriate to examine the meaning of the relevant terms. Schibeci (1984) refers to the confusion over the term 'science', establishing a difference between "scientific attitudes" and "attitudes towards science", and defining what an "attitude" is.

In terms of attitude assessment the term "science" has had many meanings associated with it (Munby, 1983). The following meanings are most common: science instruction, science careers, science itself, work of scientists, specific science issues, science as a school subject, and scientific attitudes. According to Munby (1983) there has been a problem in terms of mixing the different constructs in attitude assessments with the result being a lack of clarity as to what the attitude was towards.

There has also been confusion concerning the difference between "scientific attitudes" and "attitudes towards science". The view of Schibeci (1984) is that in general scientific attitudes refer to the supposed characteristics of scientists at work. Examples of those characteristics are: open mindedness, curiosity, honesty, scepticism, and objectivity. Gould (1982), however, has argued that these characteristics may not accurately describe scientists and contends that "*... it is abhorrent that science educators should actually attempt to mold children in the same false image.*" (Gould, 1982, 118).

When measuring attitude to science it is not always clear what is being measured. Krynowsky (1988, 576) refers to the diverse meanings including: "*feelings, opinions, beliefs in and about, and appreciations which individuals have formed as a result of interacting directly and indirectly with the various aspects of the scientific enterprise*". Munby (1983) found most measures of attitudes towards science involved an individual's feelings, beliefs, and likes towards the field of science.

Wareing (1990) contends that in the field of science education, studies of this so-called affective dimension should focus on 'attitudes towards science' as opposed to 'scientific attitudes'. For the purpose of this study Krynowsky's definition of a student's attitude towards science as a subject is used:

> "*a learned predisposition of an individual to respond in a consistently favourable or unfavourable way, to performing behaviours related to the teaching/learning of the subject.*" (Krynowsky, 1988, 579).

Effect of inquiry methods on attitude

Commenting on inquiry curricula under the auspices of the National Science Foundation (NSF) in the United States, such as the BSCS program, Johnson et al. (1974) stated that very little research has been directed at the affective aims of these programs. The most relevant of such research prior to 1974 according to Johnson, was that done by Lowry. In this study Lowry compared six 5th grade classes (n = 62) using a textbook unit on animals to six classes (n = 59) which experienced the NSF-sponsored inquiry unit on animal coloration. The Projective Tests of Attitudes designed by Lowry revealed that the students experiencing the NSF Animal coloration unit changed their attitudes about science in a positive way which was significantly greater than the changes made by the textbook group (Johnson et al., 1974).

Since then, various studies have been published that have investigated possible relationships between inquiry and attitudes. It is, however, necessary to remind ourselves of the problems and difficulties related to attitude research and in particular to show a direct relationship between a teaching strategy and changes in attitudes, considering the myriad of variables involved.

Haladyna et al. (1982) suggested that the influence of school and non-school variables on attitude towards science has not been properly considered. They proposed a theoretical model of factors that might affect attitude in this regard. Student, teacher and learning environment variables are influenced by characteristics that cannot be controlled (i.e. teacher's age, students' gender, or the building's condition) and characteristics that can be controlled (i.e. the teacher's praise and reinforcement of students, the relationship between students, or the formality of the class environment) (Haladyna et al., 1982). Simpson and Troost (1982) included attitudes towards science in school as a dimension of a broader variable they called "*commitment to science*". In their proposed model, they viewed commitment to science and achievement in science as influenced by four broad categories of variables: science, family, self and school. It seems important that, since attitude towards science may be influenced and altered by such a large variety of factors, all pertinent variables be borne in mind when examining research findings.

Johnson et al. (1974) compared the effects of different teaching situations on the attitudes of 108 sixth-grade students towards science. The three teaching situations compared were:

a) students taught by a traditional textbook method, without laboratory activities;
b) students taught by means of a combination of textbook and supporting laboratory activities; and
c) students taught in an activity-centred, inquiry situation.

The study found that students who interacted with concrete materials to answer questions developed significantly more positive attitudes than students studying similar subject matter from a textbook. The results also suggested that there was not a significant worsening of attitudes when textbook reading was mixed with materials-orientated labs in comparison with students taught by an activity-centred, inquiry approach only, than when the program was conducted without textbook reading. In a similar study (Johnson, 1976) it was also found that students perceived inquiry-orientated classes (such as those of the BSCS program) science to be more enjoyable than pupils using textbooks only as a means of instruction.

Mason and Kahle (1988) examined the effects of a teacher intervention program aimed at creating a classroom environment which nurtures student interests, curiosity and confidence, using inquiry methods of instruction. Twelve teachers were randomly selected from 64 volunteers, together with a total of 550 ninth grade students to participate in the study. The experimental groups (receiving the teacher intervention program), when compared with the control groups, had significantly higher mean scores on measures for attitudes towards science and scientists, experiences in extramural science activities, and interest in a science-related career.

The effects of discovery and expository instructional methods on the attitude of students to biology was investigated by Ajewole (1991). The sample consisted of 240 Form IV students randomly drawn from six high schools in Nigeria. The instrument used was the 40-item Scientific Attitude Questionnaire designed by the researcher. The results showed that the experimental group developed significantly more favourable attitudes to biology than the control group. It is unclear why the instrument was called the Scientific Attitude Questionnaire if it was to measure attitudes <u>towards science</u>. As the instrument was not included in the paper, questions arise as to whether it was <u>scientific attitudes</u> rather than <u>attitude towards science (biology)</u> that were actually measured.

In addition to improvements in pupils' <u>attitudes towards science</u> found by various researchers, Selim and Shrigley (1983) showed improvement in <u>scientific attitude</u> in students that had been taught by the inquiry method. Mulopo and Fowler (1987) also found that the inquiry-based approach seems to be more suitable for the teaching of <u>scientific attitudes</u> in comparison to the traditional textbook method of instruction.

Towse (1983) contends that in the design of new science courses it has often been ·med that highly student-centred, investigative courses promote more positive attitudes towards science, and that this in turn leads to a better performance in science. Towse (1983) conducted a study in Lesotho in which it was investigated whether a new course of the type described above, the Lesotho Introductory Science Improvement Programme (LISIP), promoted more positive attitudes towards science. The sample included 824 students from 11 high schools in the experimental group (LISIP program) and 904 students from 12 high schools in the control group. The instrument was the Lesotho Attitude to Science Test, a 57-item questionnaire designed by the researcher. This study showed that there was no superiority of the LISIP, either in terms of the whole group or in terms of boys and girls separately within the groups. Towse also refers to evidence from reviews of the work of Ausubel, Welch, and Ormerod and Duckworth with similar findings.

It thus seems as if studies generally show variable relations between inquiry and attitudes towards science, as results have been equivocal.

2.4.5 <u>Inquiry learning results in improvements in achievement</u>

A very significant assessment of the effects of inquiry-based science curricula on student performance was done by Shymansky <u>et al</u>. (1990). This study was based on a meta-analysis of data from more than 300 research studies spanning a period of 30 years. Meta-analysis involves summarising the results of each study by an estimate of effect magnitude and than combining these estimates across studies (Shymansky, <u>et al</u>., 1990). Meta-analysis permits the research reviewer to utilise the results of large numbers of studies while preserving information on the ways in which studies differ via indicators of study, population, and treatment of characteristics. According to Shymansky <u>et al</u>. (1990) these indicators of between-study differences can be used to determine whether the results of studies (the effect magnitudes) are systematically related to differences between studies. The results of the Shymansky <u>et al</u>. (1990) meta-analysis found the inquiry approach to have positive effects on cognitive and affective performance including achievement, process skills, problem solving and attitudes. However, contradictory results abound in studies investigating the effect of inquiry on achievement.

A study was done in Zambia in 1987 with 120 Form IV students which examined the differential effectiveness of traditional and discovery methods of instruction on achievement, understandings about science and scientific attitudes (Mulopo and Fowler, 1987). Mode of instruction and level of cognitive development were the independent variables. Results showed that the traditional group outperformed the discovery group in achievement scores. For the concrete reasoners the mode of instruction did not make a difference. For the formal reasoners, the discovery approach was found to be more effective than the traditional approach in promoting understanding about science and scientists. Mulopo and Fowler (1987) concluded that the traditional approach might be an efficient instructional mode for the teaching of scientific facts and principles to concrete thinkers, while the discovery approach seemed to be more suitable for teaching scientific attitudes and for promoting understanding about science among formal operational learners. Mulopo and Fowler (1987) did not, however, indicate what their understanding of 'discovery' is and the extent or absence of structure and guidance in their discovery approach. The nature of the test was also not elaborated on in the paper so that it is unclear whether it tested only for rote-learning.

Concerning the amount of structure to be given in an inquiry approach, Crocker et al. (1976) conducted a study in the United States on four grade six classes involving 120 pupils. In this study, two teaching strategies were operationally defined in terms of degree of teacher control over the conduct of pupil investigations. The unstructured mode was defined as one in which the teacher controlled only the area of investigation and the supply of apparatus. In the structured mode, the teacher also controlled the specific arrangement of apparatus, the specific variables to investigate, the number and type of measurement to make, and the data analysis procedures. In the structured mode, the teacher also attempted to direct the class discussion towards a specific objective. All pupils received both treatments but on different sections of work. The results reported by the researchers seem to indicate that the pupils achieved higher scores when taught in the structured mode. The researchers also indicated, however, that it is not possible to state unequivocally that the structured mode led to greater achievements or that the pupils, in general, preferred the structured mode.

Hall and McCurdy (1990) found significant improvement in achievement in a study on college students in the USA taking an introductory biology course, when taught by a BSCS-style inquiry approach. In this 15-week study, 119 students took part in comparing the inquiry-orientated BSCS approach to the more directive traditional approach. Despite better achievement by the inquiry group, no significant differences were found between the two groups regarding reasoning ability and attitudes towards biology.

2.4.6 Inquiry learning results in improved skills

Tamir (1975) refers to various studies that have shown significant differences between students who had followed an inquiry-orientated curriculum compared to those following a traditional laboratory approach in terms of the acquisition and mastery of laboratory skills. Wideen (1975) found that 4th, 5th and 6th grade students in the United States, taking the SAPA (Science - A Process Approach), an inquiry-based curriculum, had attained higher levels of cognitive and inquiry-based skills than control groups following traditional science courses. This study involved 531 students from 25 classrooms in two school districts of South Dakota, U.S.A. In a study conducted in Mexico, Rodriguez Bethel (1983) found that an inquiry approach to science and language teaching facilitated the development of oral communication skills.

Mech (1990) did a South African study comparing a traditional illustrative approach and an inquiry approach to the teaching of microscope skills to Standard 7 General Science pupils at a Johannesburg high school. Three classes comprising a total of 50 pupils were randomly assigned to use the inquiry approach, and a further three classes comprising 83 pupils, followed the illustrative approach. Three instruments were used to evaluate the effectiveness of the two approaches namely:

- a theory test designed to assess pupils' understanding of the use and functioning of the microscope;
- a practical test designed to assess the pupils' ability to use a microscope;
- a checklist used by the researcher to evaluate the ability of pupils to correctly use a microscope in terms of the steps followed and the sequence in which they were used.

The results of this study revealed that the inquiry group had significantly higher mean scores than the illustrative group in terms of the theory and practical tests. The inquiry group also showed higher levels of attainment in the acquisition of microscope skills (Mech, 1990).

2.5 THE STATE OF INQUIRY LEARNING

2.5.1 Statement of the problem

Referring to the role of inquiry in science education in the United States Welch et al. (1981, 33) state:

> *"For many years, the science education community has advocated the development of inquiry skills as an essential outcome of science instruction and for an equal number of years science educators have met with frustration and disappointment. In spite of new curricula, better trained teachers, and improved facilities and equipment, the optimistic expectations for students becoming inquirers have seldom been fulfilled."*

To determine the actual status of inquiry in the United States, Welch et al. (1981) reviewed four studies. Three of these were conducted under the auspices of the United States National Science Foundation and included a comprehensive national survey of science education, a twenty-year literature review related to high school science instruction and eleven in-depth case-studies. Welch et al. (1981) found that there was a discrepancy between the general statements about the importance of inquiry and the attention given to it in practice. When practical experiences were provided by the teachers in the studies, they were not characterised by true problem-solving, but were simply recipes to verify what was taught in theory. Furthermore, the studies reviewed by Welch et al. indicated that although teachers made positive statements about the value of inquiry, they often felt more responsible for teaching "*facts*" and "*things that show up in tests*" (Welch et al., 1981, 37).

Similar findings from three large studies under contract of the National Science Foundation (NSF) in the U.S.A. referred to by Hurd (1980) indicated that teaching Biology in the United States usually centred around one fact-laden text, and consisted of assign, recite, test, and then discuss the test. Biology teachers were found to lecture 75% of the time with over 50% basing their instruction on a single textbook. Hurd (1980,

391) concludes: "*In short, little evidence exists that inquiry is being used*".

Commentating on the state of the inquiry-orientated Nuffield Biology Project in Britain, Gould (1983) states that the predominant style of biology teaching still seems to consist essentially of the teacher first directly imparting a body of biological fact and then ensuring that this information is accurately encapsuled in the pupils' notebooks - commonly by the dictation or copying of notes. Gould's statements are based on various self-conducted observational studies as well as a review of studies conducted at Leicester University investigating the teaching styles of science teachers. Findings of the Leicester study showed that the most popular teaching style with the Biology teachers in the sample had:

- a non-practical bias;
- a relatively high incidence of statements of fact;
- relatively few teachers' questions except ones demanding factual recall;
- listening and writing as the dominant activities of the pupils, with 56% of the writing being simply copying.

In a study conducted on the teaching of biology in 80 Indian Secondary Schools in South Africa, Isaac (1993) found that:

- 87% of the practicals were of the verification type and only 13% of the investigative type;
- in all classes, the methods, materials and procedures were given by the teacher;
- in 67% of the practical lessons, there was no provision for discussion with other pupils or with the teacher;
- in 73% of the lessons there was no provision for reference to prescribed or other textbooks or journals.

Based on the findings of his study Isaac (1993) concluded that the teaching of biology at Standard Ten level in Indian secondary schools in South Africa could be classified as being "*traditional*" or of the "*expository*" type as opposed to the "*investigative*" or "*inquiry*" type.

2.5.2 Objections to inquiry learning

The study by Welch et al. (1981) into the role of inquiry in science education in the

United States found that a major problem in promoting inquiry was encountered in the preparation of science teachers. Many teachers were ill-prepared, in their own eyes and in the eyes of others, to guide students in inquiry learning. Furthermore, many teachers found inquiry approaches difficult to manage, with some considering them dangerous, especially in discipline-problem classrooms. According to Welch et al. (1981) the second major reservation teachers expressed about inquiry teaching was that it did not work for most students. They saw it as causing confusion and too difficult for any but the very bright student. In similar vein Wellington (1981) states that discovery learning is hardly conducive to classroom control and that in many carefully organised experiments the discovery is made by the quickest member of the class, often the noisiest, who then provides the rest with the answer.

In his review article Wellington (1981) asks how many science teachers, having carefully stage-managed an exciting, open-ended, 'guided discovery' experiment, have been instantly deflated by the response: *'What's supposed to happen, sir?'*. Wellington goes on to ask whether students have realised that our carefully managed open-ended discovery experiments are in many cases a long-winded way of initiating them into an accepted body of knowledge. In accordance with Wellington's views Atkinson and Delamont (1977) refer to the difficulty of and artful stage-management required to bring guided discovery off successfully. They conclude that what appears as *"discovery"* is often the recapitulation of the socially agreed nature of science and the natural world.

In an attempt to determine why most teachers do not use inquiry methods, Costenson and Lawson (1986) conducted personal interviews with twelve experienced science teachers in the Phoenix area of the United States. The top ten reasons that emerged from the interviews were listed by Costenson and Lawson (1986):

1. *Time and energy* - Too much time must be devoted to developing good inquiry materials and too much energy must be expended to maintain enthusiasm through five classes each day.
2. *Too slow* - The class will not cover all the material in the district curricula and will therefore not know all they need to know.
3. *Reading too difficult* - Most students have difficulty reading the inquiry texts, as the text places higher demands on student reasoning ability.
4. *Risk is too high* - The administration will not understand what is going on and think the teacher is doing a poor job.

5. *Tracking* (i.e. having different levels at which students can follow a subject e.g. Advanced or Regular Biology; Higher Grade or Standard Grade) - The students cannot do the inquiries because there are no "formal" thinkers left in regular Biology.
6. *Student immaturity* - Students are too immature to take responsibility for their own learning. Students waste too much time and, therefore, will not learn enough.
7. *Teaching habits* - It is difficult to change teaching habits that have been used for a long time.
8. *Sequential text* - Inquiry textbooks lock you into the order of the book and it becomes impossible to change the order of presentations as there is too much new material in each section of work with constant referral to previous material.
9. *Discomfort for both teachers and students* - Teachers feel uncomfortable not being in control of what is going on. Students also feel discomfort.
10. *Too expensive* - Laboratories are not adequately equipped for inquiry.

Costenson and Lawson (1986), however, argue convincingly against all ten of the above reasons for not using inquiry and state that these reasons are not sufficient to prevent its use. Similar objections to inquiry are raised by Lock (1994) in his review of the 26 years of the inquiry-orientated Nuffield Advanced Biology in Britain. Lock lists criticisms that have been levelled at the Nuffield course but does not present data to back these claims. The criticisms against the Nuffield course include:

- The course is too long to teach. Some teaching centres find that it is not possible to cover the course within the teaching time allocated.
- The course is seen as costly in terms of the books, resources, animals and plants, and the equipment and chemicals that are needed for it.
- The course itself is considered difficult by some teachers. Teachers new to teaching find it contrasts with the way they were taught at school and at university or college. Consequently the level of support needed by such teachers may be quite high.
- Practical work planned to lead students to an understanding of key concepts is not structured enough. Lock (1994), however, also refers to others that feel there are too many recipe-type practical activities and that practicals are frequently closed-ended.

Despite the objections raised against the Nuffield Advanced Biology course, Lock (1994) contends that arguments against inquiry are weak. It is Lock's opinion that the course is unique in that it produces students who think, study, and act independently. And in addition it challenges and stimulates teachers and gives them prestige.

2.6 CONCLUDING REMARKS

The literature review has provided insight into various aspects of inquiry learning. The historical development of inquiry approaches was discussed together with contemporary arguments supporting inquiry. Issues relating to criticism of inquiry were also raised. Various studies were consulted that have investigated the influence of inquiry learning on a number of dependant variables. It is the opinion of this writer that the equivocal research findings may be due to the confusion surrounding the term 'inquiry' with it having different meanings to different researchers. Methodological limitations in educational research may also contribute to the equivocal research findings. Relatively small samples often used in educational research seldom show significant differences, but that does not necessarily mean that there aren't any.

Chapter 3 - Research methods and collection of data

In this chapter the research methods used in the current study are discussed. This includes a discussion on the development of an inquiry-orientated 'teaching package' as well as the development of the instruments used in the study. The details of the research design, the sample, the collection and analysis of data are also elaborated on.

3.1 DEVELOPMENT OF TEACHING PACKAGE

An inquiry-orientated teaching package dealing with the human circulatory system was designed by the researcher (see Appendix A on page 78). This package comprised a teacher information sheet for each lesson as well as master copies of worksheets to be used by the Standard Eight Biology pupils. The information sheet stated the purpose of the lesson, the required materials and equipment, and the procedures and suggested approach to be followed.

The pupil worksheets were so designed that the pupils use active investigation to discover information about the circulatory system for themselves so that the teacher was not the source of knowledge. The worksheets make the pupil take the role of investigator whilst the teacher takes on a guiding and supportive role.

Various aspects were considered in the design of the worksheets including:

- clear and unambiguous writing,
- neat layout and presentation,
- the precise wording of instructions,
- well drawn diagrams and illustrations,
- whether the content meets the stated lesson objectives,
- sufficient answering space.

One of the aims of the pilot study was to determine whether any problems existed with these aspects.

The inquiry worksheets deal with various aspects of the circulatory system including:

Lesson 1 - An historical introduction to the circulatory system.
- Investigation 1 (observing *Daphnia* under microscope) to give pupils an opportunity to see a living heart in action and make observations and deductions regarding the role of the heartbeat.

Lesson 2 - Examination of mammalian heart.
- Investigation 2 (external examination and dissection of heart) to allow pupils to become familiar with the heart's structure and to relate structure to function.

Lesson 3 - Listening to the sounds of the heart (investigation 3).
- Investigation of the effect of exercise on the heart rate (investigation 4).

Lesson 4 - Examination of skeletal and heart muscle tissue and the structure of arteries and veins using biostrips and bioviewers (investigation 5).
- Conducting Harvey's experiment to discover some of the structural and functional properties of veins.

Lesson 5 - Observing capillary circulation in goldfish to heighten understanding of blood capillary functioning (investigation 7).
- Experiment to demonstrate the importance of elasticity of arteries (investigation 8).

Lesson 6 - Relating blood pressure fluctuations to the cardiac cycle.
- Blood pressure and the functioning of capillary networks.
- The origin of lymph and the functioning of the lymphatic system.

Lesson 7 - Systemic circulation and the pathways of blood to and from various body organs.
- The hepatic portal system and the absorption of nutrients.

The various references which served as a basis for the development of the inquiry worksheets are listed in Appendix B on page 119.

3.2 INSTRUMENTS USED IN THE STUDY

Two tests were used in this study. A theory test was used in order to establish whether pupils had understood the work covered on the circulatory system. This may be done by determining whether learnt concepts can be applied by pupils in different contexts to solve unseen problems. An *Attitude Towards School Biology Test* was used in order to determine whether pupils receiving inquiry-orientated instruction developed more favourable attitudes towards biology as a school subject than did pupils receiving expository instruction.

3.2.1 Test of Understanding (TOU)

A theory test (see Appendix D on page 129) was used by the researcher to test pupil understanding of the circulatory system. A few recall questions were included but most questions corresponded to higher levels of Bloom's Taxonomy, namely comprehension and application. The questions used in the test were modified from questions in Bailey et al. (1989); Austoker and Wessels (1987) and Bennetts et al. (1989).

The aims of the questions in the test were as follows:

- **Question 1** determines whether pupils can use their knowledge of the functions of the circulatory system and apply it to answer questions relating to the structure of foetal circulation. Pupils are also required to predict the result of certain structural errors in adult circulation.

- **Question 2** requires pupils to name and list in correct sequence blood vessels and other structures through which a blood cell would travel from one point in the body to another. Pupils must recall the names of blood vessels but in order to list them in the correct sequence, they must show an understanding of the pathway of blood through the body.

- **Question 3** determines whether pupils understand the significance of the difference in thickness of the walls of atria and ventricles. An explanation is also required as to the reason why the left ventricle of the heart has thicker walls than the right ventricle.

- **Question 4** requires pupils to compare blood circulation to a bus route. Certain terms must be and a reason given as to why the terms are comparable. This question aims to determine whether pupils understand the functions of the circulatory system.

- **Question 5** determines whether pupils are able to analyse and interpret a statement regarding the functioning of the circulatory system by explaining the meaning of the statement.

- **Question 6** depicts a diagram (of a circulatory system) which includes certain errors. Pupils are required to identify and list the errors on the diagram in comparison to mammalian blood circulation. Pupils are also required to analyse an early hypothesis of the movement of blood through the heart and indicate with arrows on a diagram how the early view differs from that currently held.

- **Question 7** requires pupils to specify the differences in the composition of arterial and venous blood.

As was the case with the worksheets, various aspects were considered in the test construction, including

- clear and concise instructions,
- readability and presentation of the test,
- clarity of diagrams, and
- correct and applicable content.

3.2.2 Attitude Towards School Biology Test

Various aspects of the criticism levelled against attitude research in science education were reported in Chapter 2. These include:

- the constructs of attitude and science are often vague, inconsistent and ambiguous;
- research has often been conducted without the basis of a theoretical model of the relationship of attitude with other variables;
- the attitude instruments used are often judged to be immature and inadequate.

The major problem according to Munby (1983) and Schibeci (1984) is that most instruments do not provide appropriate psychometric evidence of reliability and validity. Germann (1988) refers to a study conducted by Munby in which he collected 204 attitude instruments. Fifty-six of these purported to measure attitude towards science, whilst the remainder measured scientific attitude. Only 21 of these were used in more than one study. Of the 56 measures, 21 did not report any reliabilities. Thirty-one of the remaining reported reliabilities greater than 0,7. Only seven instrume verified their reliability findings in a second study (Germann, 1988).

Validity of the attitude measures fared no better in Munby's critique. Eighteen of the selected measures of attitude to science reported no evidence of validity. Nine used a panel of judges with no supporting psychometric evidence of validity. Only seven instruments verified their validity by more than one method (Germann, 1988). In summary Munby found no instruments that he did not consider suspect for one reason or another. Germann (1988, 692) quotes Munby as saying:

> *"With very few exceptions, it is clear that authors of instruments are not taking all the steps they might to assure that their instruments may be used with confidence. And what is equally distressing to find is that other users seem to take validity and reliability for granted."*

For the purpose of this study a fourteen-item Likert-type instrument, the *Attitude Toward Science in School Assessment* (ATSSA) developed by Paul Germann of Maine, U.S.A. was used (Germann, 1988). It was considered to be the most appropriate for the current study for a number of reasons. Firstly, the instrument was developed to measure a single dimension of a general attitude towards science, specifically, how students feel towards science as a subject in school. Attitude as defined in this instrument does not include such scientific attitudes that might motivate a person to become a scientist. Nor does it include other attitudes towards science such as attitudes towards scientists. Other domains not included were that of personal ability in science, the value of science to the individual, or the value of science to society (Germann, 1988). In accordance with the aims of the current study the selected instrument aims to measure a general attitude towards science in school without confounding the interpretation by including other dimensions of *attitude* or *science*.

The development of the ATSSA included extensive pilot testing by Germann (1988). From an initial list of 34 positive and negative statements 10 statements were removed after inspection by a panel of judges. The judges evaluated the items for construct validity and clarity. A Likert scale was devised for student responses and the remaining 24 items were pilot-tested with a group of 125 science students in Grades 7 and 8. A Cronbach alpha reliability of 0,93 was found (Germann, 1988). However, it must be borne in mind that reliability is context specific and that the high levels of reliability of the test reported by Germann (1988) cannot be assumed in any other administration of the test.

Germann (1988) then submitted 24 items to principal-component factor analysis. Fourteen items were found to load on a factor that best fitted the desired construct of general attitude towards science. The new 14-item instrument was then further field-tested. The four studies in which the instrument was used all showed Cronbach alpha estimates of reliability greater than 0,95.

Germann is of the opinion that if an attitude instrument is useful, it should be able to distinguish between two causes, one of which fosters a negative attitude and the other which fosters a more positive attitude. Germann (1988) provides evidence, from field studies, of the ability of the ATSSA to discriminate between these two causes.

For the purpose of this study the word "science" was replaced with the word "biology" in all the items of the test. The name of the test was also changed to the *Attitude Towards School Biology Test.* This was done so as not to confuse the pupils as biology is the science investigated in this study.

3.3 PILOT STUDY

The inquiry teaching package, the *Test of Understanding*, and the *Attitude Towards School Biology Test*, were pilot-tested at a Pretoria high school. This state-subsidised (Model C) school is very similar to the school used in the main study in terms of the racial mix of pupils, socio-economic background of pupils and facilities.

3.3.1 Sample

One class comprising 29 Standard 8 biology pupils was used in the pilot study. Thirteen of them were boys and 16 were girls. Eighteen of the pupils were white and eleven black. They had an average age of 16 years. Three of the pupils were repeating Standard 8.

The teacher of the class was a 33 year-old white female teacher with ten years of teaching experience. She holds a B.Sc (Honours) degree and is thus well qualified. This teacher proved to be very co-operative and was enthusiastic about taking part in the pilot study.

3.3.2 Procedure

The researcher provided master copies of the worksheets to the teacher for duplication well in advance of the commencement of the study. Also included in the "package" was an information sheet outlining the purpose of the lesson, the requirements (in terms of materials needed) and the suggested approach. A lesson evaluation sheet to be completed by the teacher after each lesson was also included. This was used to get feedback from the teacher with possible suggestions to improve the worksheets. The researcher provided various materials and specimens which the teacher may not have had access to, and delivered these in good time. e.g.

Lesson 1: *Daphnia*
Lesson 2: 8 ox hearts
Lesson 3: 16 stethoscopes
Lesson 4: 16 bioviewers and strips
Lesson 5: 8 goldfish and 8 one-way plastic pumps.

3.3.3 Evaluation of package

The following feedback was received:

Lesson 1: More time was needed to complete investigation 1. Pupils had to rush to finish. The fact that a thermometer was required for each group was not included on the list of requirements on the information sheet. The teacher did fortunately have thermometers in her laboratory so that is did not present too much of a problem. Insufficient answering space had been provided for some of the questions.

It was reported that the pupils enjoyed the lesson and were particularly fascinated to see *Daphnia*'s heart beating. The teacher commented that investigation 1 *"provided a good visual image of the heart as it pumps"*.

The corrections and alterations of worksheet 1 were done and it was decided that in view of the time problem, lesson 1 would be divided into two one-hour sessions for the main study i.e. the introduction and historical background in one hour and the *Daphnia* investigation in a second one-hour period.

Lesson 2: Pupils were hard-pressed to complete the dissection. Some pupils were 'overwhelmed' by the experience and got carried away, not following worksheet instructions regarding the procedure to be followed. Another practical problem that arose was that pupils had difficulty answering questions on the worksheet because their hands were dirty and bloody. There were a few pupils who had reservations about dissecting the heart and preferred to be spectators. However, most pupils enjoyed the dissection tremendously.

In view of the problems it was decided that in the main study worksheet 2 would be given to pupils at the end of the previous lesson so that they could familiarise themselves with the procedures to be followed the next day, in an attempt to save time. Furthermore, the lessons in the main study were planned so as to have the dissection in a period ahead of a school break, so that the worksheet would definitely be completed, even if it meant working into the break.

Lesson 3: Once again, time was a problem. The pupils really enjoyed working with stethoscopes and the teacher reported that pupils found the personal relevance interesting.

In view of the time factor it was decided that in the main study the entire double period would be used to check the answers to worksheet 1 and 2. Investigations 3 and 4 would be carried over into the next double period.

Lesson 4: This went off without any problems. The pupils enjoyed the bioviewer study, particularly as they had not used bioviewers before.

Lesson 5: There was sufficient time to complete investigations 7 and 8. Most pupils were fascinated by seeing the blood flowing in the goldfish tail capillaries and really enjoyed the lesson. There were, however, a few pupils who could not be convinced that the goldfish would not come to any harm if kept moist, and they did not want to participate in the practical work. A practical problem that arose was that in some cases the goldfish was bigger than the petri-dish, resulting in portions of it hanging awkwardly over the edge.

The one-way pump investigation provided opportunity for some pupils to squirt each other with water, but it was reported that it really helped the pupils to understand the importance of artery walls being elastic.

Lesson 6: There was not sufficient time to check the previous investigations as well as to complete worksheet 6. This resulted in pupils having to do additional homework. It was thus decided that in the main study this double period would be used only for checking and that worksheet 6 would be kept back for the next double lesson.

Lesson 7: There was insufficient time allowed for the completion of worksheet 7 together with checking the previous investigations. For the main study it was therefore decided that the entire double lesson would be used for checking answers to the questions of the previous investigations 7 and 8. An additional double period would be used to complete worksheet 7 and check it thereafter.

Overall, the feedback of the piloting of the inquiry teaching package was very positive. The teacher involved felt that the pupils really enjoyed the lessons and that they had learnt a lot in an exciting way. The teacher also expressed the desire to use more of the inquiry approach in the planning of her biology lessons in future.

3.3.4 Piloting the testing instruments

The *Attitude Towards School Biology Test* was administered to the same sample of pupils that underwent the piloting of the teaching package. This was done in order to determine whether any problems existed with the instructions given, readability or layout of the items. This was done by having the teacher involved ask the pupils whether they had any problems in reading or understanding the instructions and questions. No questions or queries arose during the completion of the 14 items of the test by the pupils. The teacher was also instructed by the researcher to question the pupils before collecting the papers as to whether any other problems existed with any of the 14 items. This was done and no problems were forthcoming.

The *Test of Understanding (TOU)* was piloted on the sample of pupils one week after completion of the inquiry teaching package dealing with the human circulatory system. No problems were reported by the pupils or by the teacher regarding the instructions given, readability of the questions, the layout, or with the clarity of the diagrams and illustrations.

The test papers were marked by the researcher and the following results were obtained:

Number of pupils (n)	= 29
Mean percentage score	= 49,06%
Class mean score out of 65	= 31,9
Median	= 35 (53,8%)
Range	= 41
Average deviation	= 8,61
Standard deviation	= 10,66
Cronbach alpha reliability	= 0,92

The mean score of the class for this test was ±10% lower than the class average of the most recent biology examination result for that particular class. This drop in percentage means was expected, as the theory test included very few recall questions, with the majority of questions examining <u>understanding</u> of concepts. It seems to be a fact that most South African pupils rely on rote-learning, and can achieve better marks as a consequence. It was decided that the results of the pilot study of the *TOU* did not warrant any changes to the test. Minor changes were suggested by the research supervisor to the marking memorandum of the *TOU*.

3.4 THE MAIN STUDY

3.4.1 Research design

Two research designs were used in this study. For the assessment of pupil attitude towards biology as a subject at school an Untreated Control Group Design with Pretest and Posttest was used (Cook and Campbell, 1979).

Treatment group	$\underline{O_1 \rightarrow X_2 \rightarrow O_2}$
Control group	$O_1 \rightarrow - \rightarrow O_2$

O_1 = Pretest
O_2 = Posttest
X = Treatment (inquiry teaching package)

For the evaluation of pupil understanding a Posttest-only Design with Nonequivalent groups was used (Cook and Campbell, 1979).

Treatment group	$\underline{X_1 \rightarrow O}$
Control group	$- \rightarrow O$

X_1 = Intervention (inquiry teaching package)
O = Posttest

3.4.2 Sample

Two Standard Eight Biology classes (n = 64) from a Model C (state-aided) Pretoria high school were used in the main study. Socio-economically the school environment can be described as middle class. The school was used because easy access was available to the researcher, as the researcher is employed at the school (although he was away on study leave the year the research was done).

The sample used was non-randomised and unequivalent, as the use of two intact classes was all the researcher could use because of timetable constraints. The spin of a coin, however, determined which one of the two classes would receive the inquiry package (the experimental group).

The inquiry group was made up of 35 pupils with the majority of pupils being 16 years old. There were 30 white and 5 black pupils in the class. The expository group had 29 pupils (26 white, 2 black and 1 Indian), with the majority of pupils also being 16 years old. Pupils were allocated to the two classes at the beginning of the year on the basis of subject choices and not on the basis of achievement. Each of the two classes had roughly the same number of pupils from 8A, 8B, 8C, 8D etc.

3.4.3 Procedure

- **Attitude pretest**

  The pretest of the *Attitude Towards School Biology Test* was administered three months prior to the start of the inquiry teaching package. This was done so as not to have the pre- and posttest too close to each other as it was thought that the pupils may be susceptible to persuasion and answer as they did before, if this was the case.

- **Teaching of package**

  The inquiry package was not taught by the researcher but by the teacher who had been teaching the two classes throughout the year. This was done so as not to have pupils know that an experiment was being conducted. Possible researcher bias would also be eliminated with the chosen approach. The teacher who taught the package was a 51-year old male with a doctorate in physiology, with 8 years of teaching experience at school level (he also has extensive experience in scientific research and tertiary education).

  The teaching of the package proceeded with arrangements made regarding time, allocation of periods for completion of worksheets and general planning in accordance with the outcome of the pilot study. As was the case with the pilot study, the researcher provided various specimens, equipment and materials that the school did not have. These were all delivered to the school in good time.

  The expository group proceeded with the typical lecture-type approach to their lessons. Pupils in the expository group were occupied during lessons by listening to the teacher's explanations, copying down notes and drawing diagrams from the textbook into their notebooks. A practical session involving a dissection of a heart was held at the end of the section of work. Although practical work was done this was not "inquiry". The practical served to verify factual content that was previously "exposed" by the teacher through lecturing etc. The pupils were thus passive recipients of factual information given by the teacher. This method can be categorised as an "expository approach".

Posttests

The posttest of the *Attitude Towards School Biology Test* was administered to both groups two days after the completion of the teaching package to the inquiry group. (The expository group had completed the section of work on the human circulatory system 5 days before).

The *Test of Understanding* was administered to both groups on the same day i.e. one week after the completion by the inquiry group of the teaching package. The administering of both the posttests went off without any difficulties.

3.5 ANALYSIS OF DATA

3.5.1 *Test of Understanding (TOU)*

The *inquiry* and *expository* group results on the *TOU* were compared using descriptive statistics, and are presented in Chapter Four by means of tables and graphs. An analysis of covariance (ANCOVA) using the school's most recent Biology examination result as the covariate, was used to determine whether differences in mean scores between the two groups were statistically significant or not. ANCOVA enables the adjustment of the posttest mean scores for each group to compensate for the initial differences between the groups.

Separate means and standard deviations were also calculated and tabulated for the higher and standard grade pupils in each group. ANCOVA was also used to determine whether differences in Higher Grade means and Standard Grade means between the two groups were statistically significant or not.

Item analysis was conducted for four items on the theory test [questions 1(a) and (b); and 3(a) and (b)]. These were the items which were thought to test understanding rather than factual recall, and they were used in order to compare the results of the item analysis for the two different teaching approaches.

3.5.2 ***Attitude Towards School Biology Test***

Raw scores of the *Attitude Towards School Biology Test* (pre- and posttest) for both groups were analysed using descriptive statistics and presented using tables and graphs. An analysis of covariance was used to determine whether differences in posttest mean scores between the inquiry and expository groups were statistically significant or not. Pretest scores were used as covariates to compensate for initial differences in attitudes of the two groups prior to intervention.

An item analysis was conducted for three selected items (3, 6 and 8) from the *Attitude Towards School Biology Test.* Studies by Johnson (1976), Mason and Kahle (1988) and Ajewole (1991) have shown that students find inquiry-orientated classes to be more enjoyable than expository-orientated classes. The three named items focus on the aspect of enjoyment, so it was decided to compare pupils' responses of the two groups with regard to this aspect. A chi-square test was used to determine whether differences between expected and obtained frequencies of particular responses by the pupils to items 3, 6 and 8 were significant or not. In Chapter Four the results obtained are presented and discussed.

Chapter 4 - Analysis and Discussion of Results

This chapter describes the results obtained using the two research instruments described in the previous chapter. The *Test of Understanding* was designed to test pupil understanding of the human circulatory system. *The Attitude Towards School Biology Test* measures a single dimension of a general attitude towards science - specifically, how pupils feel towards biology as a subject in school. These instruments were used to determine whether a difference existed between the inquiry and expository approaches to teaching (as used in this study), with respect to pupil understanding of the human circulatory system and pupil attitude towards biology as a school subject.

4.1 RESULTS OF THE *TEST OF UNDERSTANDING* (TOU)

Levels of understanding as reflected by the marks achieved by the pupils in the inquiry group on the *TOU* were compared to those of the pupils in the expository group. This was done to determine whether any difference existed between the two groups in terms of pupils' understanding of the human circulatory system.

4.1.1 Whole class comparisons

Table 1 shows the descriptive statistics of the raw scores for the Test of Understanding (TOU).

Table 1: *Descriptive statistics for the TOU (whole class comparisons)*

	Inquiry group	Expository group
Sample size	n = 31	n = 26
Mean score (out of 64) - TOU	19,71	19,07
Mean % - TOU	30,8	29,8
Standard deviation (of % scores)	19,1	19,5

Levels of understanding as reflected by the mean scores of both the inquiry and expository groups are similar, and very low. The inquiry group has a 1% higher TOU mean than the expository group. Values indicating the distribution of scores (standard deviations) also show similarity with the high levels of variability of scores around the mean in both groups.

In order to determine whether differences in TOU scores of the two groups are statistically significant or not, an analysis of covariance (ANCOVA) was performed, to compensate statistically for initial differences between the two groups. The June exam scores were used as the covariate. The results of the analysis of covariance for the TOU scores are presented in Table 2.

Table 2: *Analysis of covariance for TOU scores (using June exam scores as covariates)*

Source	Degrees of freedom	Sum of squares	Mean square	F value
Group	1	422,65	422,65	
Test	1	4593,46	4593,46	
Group x Test	1	151,65	151,65	0,58

Analysis of covariance on the results of the TOU for the two groups yields an F-value (0,58) that indicates no significant difference between the inquiry and expository groups at the 0,05 level of significance after the initial differences between the groups has been taken into account. This means that there is a greater than 5% chance that the difference in mean scores of the two groups is due to chance.

Looking at mean scores of the TOU (as an indication of the level of understanding achieved) did not reveal any difference between the two groups. It was therefore decided to look at the distribution of scores to determine if any trends were detectable. Table 3 (on the following page) shows the percentages of pupils in the inquiry and expository groups respectively scoring within the mark ranges shown. The table shows relatively high percentages of pupils from both groups in the low mark ranges. Both the inquiry and expository groups have half the class with a score of less than 17 out of 64. The expository group has almost a quarter of the class in the 0 - 8 mark range, whilst only 16% of the inquiry group scored as low as this. However, 35% of the pupils in the inquiry group scored in the (9 - 16) range with fewer of the expository pupils (27%) scoring in this range. The majority of pupils in both groups thus revealed a low level of understanding of the content. The percentages of pupils in the higher mark ranges (with higher levels of understanding) are low for both groups and a very similar distribution pattern is observed for the two groups. One pupil in the inquiry group managed a score in the 49 - 56 range with no pupils in the expository group scoring in this range. The results of the TOU thus reveal a positively skewered distribution curve for both groups (see Figure 2 below) indicating that only a small number of pupils had demonstrated a thorough understanding of the work. (See discussion on page 56 concerning the use of parametric statistics on small samples and in the absence of normal distributions).

Table 3: Percentages of pupils in the inquiry and expository groups scoring within a specific mark range on the TOU

	Number of pupils	
Mark range	Inquiry group (n = 31)	Expository group (n = 26)
0 - 8	5(16%)	6(23%)
9 - 16	11(35%)	7(27%)
17 - 24	5(16%)	4(15%)
25 - 32	5(16%)	4(15%)
33 - 40	3(10%)	4(15%)
41 - 48	1(3,2%)	1(3,8%)
49 - 56	1(3,2%)	0
57 - 64	0	0

The trends in the data are more easily compared when the results are shown graphically (See Figure 2 below).

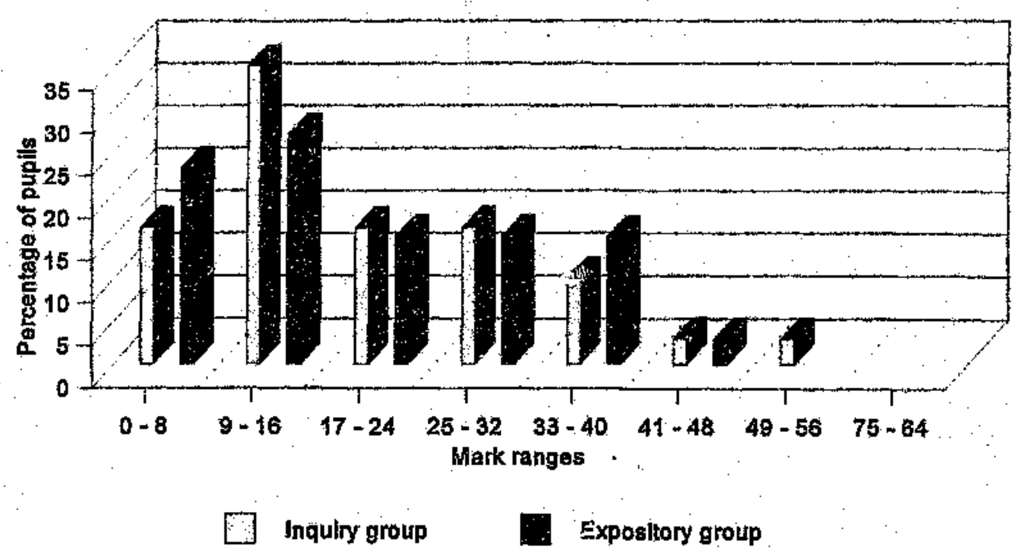


Figure 2: Comparative bar chart showing the percentages of pupils in the inquiry and expository groups scoring within specific mark ranges.

The results indicate that pupils performed poorly on the *Test of Understanding*. It also indicates that the inquiry package used in this study did not result in pupils developing a better understanding of the circulatory system than pupils receiving expository teaching, as had been expected. This was disappointing, as the mean percentage of the inquiry group is almost 19% lower than that achieved by the inquiry sample used in the pilot study.

One possible reason for the disappointing results may be the unfortunate circumstances that preceded the commencement of the teaching of the inquiry package. The two classes involved in the study were not 'taught' for the two weeks leading up to the main study. This was due to a colleague in the science department falling ill and the teacher involved in the main study being called upon to teach the matriculants in preparation of their final examinations, rather than teaching his own classes. This resulted in the Standard Eight pupils involved in the study doing unsupervised 'self-study' for two weeks prior to the start of the study. It may thus be that the pupils had become unaccustomed to working hard at the start of the study and therefore might not have completed the inquiry worksheets as diligently and as thoroughly as was required. This would have resulted in pupils not developing the expected levels of understanding of the content. It must, however, be said that the teacher involved in the study indicated that the pupils worked diligently in completing the inquiry worksheets throughout the study. However, he also reported that pupils often answered the questions superficially and not as in-depth as expected. Pupil answers were *"not particularly incorrect answers but vague answers as if the pupils have difficulty in expressing themselves in describing what they see. Easier to provide oral answers"* (See teacher feedback on page 126).

4.1.2 Comparison of scores of Higher Grade pupils in the two groups

Costenson and Lawson (1986) express the view that inquiry learning places greater demands on student reasoning ability. They hold the opinion that most high school students are "concrete operational" in the Piagetian sense and that inquiry is guided by "formal operational" reasoning. A study by Hall and McCurdy (1990) showed that in their sample of 119 college students 60% of them operated below the Piagetian formal operational development stage.

In South Africa pupils take their school subjects on one of two academic levels i.e. "Higher Grade" and "Standard Grade". Greater cognitive demands are placed on pupils on the Higher Grade, and it is required that at least 40% of questions in the final examination should assess higher cognitive skills such as analysis, synthesis and evaluation. Pupils in Standard Grade deal with less content (shorter syllabus) and are predominantly tested with factual recall questions. The researcher of the study discussed in this report thought that the "Standard Grade" pupils present in the sample used would be "concrete operational". It was therefore decided by the researcher to look separately at the performances of the Higher Grade and Standard Grade pupils on the TOU. Table 4 shows a comparative summary of the scores of the Higher Grade pupils.

Table 4: Comparative descriptive statistics of Higher Grade pupils' scores for the TOU

	Inquiry group	Expository group
Sample size	20	18
Mean score (out of 64) - TOU	24,76	19,58
Mean % - TOU	38,7%	30,6
Standard deviation (of % scores)	19,3	20,69

The pupils in the inquiry group achieved a 7% higher mean percentage in the June exam (three months prior to this study) than those in the expository group. It may thus be that the Higher Grade pupils in the inquiry group were capable of better achievement than those in the expository group at the start of the study. The 8% higher achievement by the Higher Grade inquiry pupils than the Higher Grade expository pupils on the *Test of Understanding* may thus not be significant. In order to check whether differences in TOU mean scores of the Higher Grade pupils in the two groups are statistically significant or not, an analysis of covariance was performed, despite the small sample and the absence of a normal distribution of scores. According to Borg and Gall (1989) the level of significance is influenced to a considerable degree by the size of the sample. By nature of the formulae used to determine significant difference, the smaller the sample size, the bigger the difference needed to reach a given level of significance.

Parametric statistics make certain assumptions about population parameters, one being that the scores are normally distributed about the mean. When large deviations from

In South Africa pupils take their school subjects on one of two academic levels i.e. "Higher Grade" and "Standard Grade". Greater cognitive demands are placed on pupils on the Higher Grade, and it is required that at least 40% of questions in the final examination should assess higher cognitive skills such as analysis, synthesis and evaluation. Pupils in Standard Grade deal with less content (shorter syllabus) and are predominantly tested with factual recall questions. The researcher of the study discussed in this report thought that the "Standard Grade" pupils present in the sample used would be "concrete operational". It was therefore decided by the researcher to look separately at the performances of the Higher Grade and Standard Grade pupils on the TOU. Table 4 shows a comparative summary of the scores of the Higher Grade pupils.

Table 4: *Comparative descriptive statistics of Higher Grade pupils' scores for the TOU*

	Inquiry group	Expository group
Sample size	20	18
Mean score (out of 64) - TOU	24,76	19,58
Mean % - TOU	38,7%	30,6
Standard deviation (of % scores)	19,3	20,69

The pupils in the inquiry group achieved a 7% higher mean percentage in the June exam (three months prior to this study) than those in the expository group. It may thus be that the Higher Grade pupils in the inquiry group were capable of better achievement than those in the expository group at the start of the study. The 8% higher achievement by the Higher Grade inquiry pupils than the Higher Grade expository pupils on the *Test of Understanding* may thus not be significant. In order to check whether differences in TOU mean scores of the Higher Grade pupils in the two groups are statistically significant or not, an analysis of covariance was performed, despite the small sample and the absence of a normal distribution of scores. According to Borg and Gall (1989) the level of significance is influenced to a considerable degree by the size of the sample. By nature of the formulae used to determine significant difference, the smaller the sample size, the bigger the difference needed to reach a given level of significance.

Parametric statistics make certain assumptions about population parameters, one being that the scores are normally distributed about the mean. When large deviations from these assumptions are present in the research data, parametric statistics should not be used (Borg and Gall, 1989). Borg and Gall (1989, 561), however, recommend the following:

> *"When research data meet the assumption of being interval scores but do not meet the assumptions of normal distribution and variance homogeneity, we still advise you to use one of the parametric statistics ..."*
> *"The main reasons for recommending the use of parametric statistics in these situations are that: (1) studies have shown that moderate departure from the theoretical assumptions has very little effect upon the value of the parametric technique; (2) non-parametric statistics are generable less powerful, that is, they require larger samples in order to yield the same level of significance; and (3) for many problems encountered in educational research, suitable non-parametric tests are not available."*

The results of the analysis of covariance are presented in Table 5 below.

Table 5: *Analysis of covariance of Higher Grade pupils' scores on the TOU (using June exam results as covariates)*

Source	Degrees of freedom	Sum of squares	Mean square	F value
Group	1	960,463	960,463	
Test	1	2442,388	2442,388	
Group x Test	1	0,2516	0,2516	0,001

Analysis of covariance for Higher Grade posttest scores on the *Test of Understanding* reveal no significant difference (F value = 0,001) between the experimental and comparison groups at the 0,05 level of significance. There is thus a greater than 5% chance that the difference in mean scores of the Higher Grade pupils of the two groups is due to chance.

The results therefore indicate that the Higher Grade pupils in the inquiry group did not develop a significantly better understanding of the circulatory system than the Higher Grade pupils in the expository group.

4.1.3 Comparison of scores of Standard Grade pupils in the two groups

Comparisons between the levels of understanding of pupils as reflected by the performances of the Standard Grade pupils in the inquiry group and comparison groups are presented in Table 6 on the following page.

Table 6: Comparative descriptive statistics of Standard Grade pupils' scores for the TOU

	Inquiry group	Expository group
Sample size	11	9
Mean score (out of 64) - TOU	10,4	17,7
Mean % - TOU	16,3%	27,7%
Standard deviation (of % scores)	18,1	16,4

The Standard Grade pupils in the comparison group achieved an 11,4% higher mean score than those of the inquiry group. Furthermore, the inquiry pupils showed a drop of 23,7% in mean score compared to their June mean percentage. The comparison group showed a much smaller drop of 7,3%. The comparison group also revealed a smaller standard deviation indicating less variability of scores around the mean compared to the inquiry group.

These results seem to indicate that Standard Grade pupils in this sample have benefitted more in terms of understanding the circulatory system from a structured traditional lecture approach than from an inquiry approach. The small number of Standard Grade pupils in each group, however, make any generalisable inferences impossible.

An analysis of covariance was performed to determine whether the 11,4% difference in mean score between the groups was statistically significant. The results of the analysis of covariance are presented in Table 7 below.

Table 7: Analysis of covariance of Standard Grade pupils' scores on the TOU (using June exam results as covariates)

Source	Degrees of freedom	Sum of squares	Mean square	F value
Group	1	3,4897	3,4897	
Test	1	3148,23	3148,23	
Group x Test	1	766,688	766,688	7,81

Analysis of covariance for Standard Grade posttest scores on the *Test of Understanding* reveals no significant differences between the experimental and comparison groups at the 0,05 level of significance. It must be borne in mind that the small samples involved make it very unlikely to obtain statistically significant results, even if differences exist.

It appears that Standard Grade pupils benefit more from a more traditional approach to teaching which does not require them to think or to take responsibility for their own learning. The results, however, showed no significant differences.

4.1.4 <u>Item analysis of TOU questions 1a and b; 3a and b</u>

Questions 1(a) and (b); 3(a) and (b) are considered by the researcher to be questions that test understanding rather than factual recall only. It was decided to see if there were any differences in pupils' responses to these specific questions by pupils of the inquiry and expository groups. It was thought by the researcher that pupils that had used the inquiry approach to learning about the circulatory system may have developed a higher level of understanding.

The inquiry and expository groups pupils' responses to question 1(a) and 1(b) of the TOU (based on the blood system of a human foetus; see test questions *Appendix D on page 130* and marking memorandum *Appendix E on page 135*) are compared in terms of the number and percentage of pupils in each of the following categories:

- No understanding - (no correct and relevant statement - 0 marks)
- Slight understanding - (at least one statement that can be regarded as relevant and correct - 1 mark allocated)
- Partial understanding - (two or three relevant and correct statements, but answer not complete; 2 - 3 marks allocated)
- Full understanding - Four correct and relevant statements, answer complete - 4 marks allocated.

The results of the analysis for question 1 are shown in the following table:

***Table 8:** Number and percentage of pupils in each 'category of understanding' for questions 1(a) and (b) of the TOU*

	Extent of understanding							
Question	**None (0 marks)**		**Slight (1 mark)**		**Partial (2 - 3 marks)**		**Full (4 marks)**	
	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)
1 (a)	23(74,2%)	23(88,5%)	5(16,1%)	0(0%)	1(3,2%)	1(3,8%)	2(6,5%)	2(7,7%)
1 (b)	20(64,5%)	17(65,4%)	7(22,6%)	6(23%)	2(6,5%)	3(11,5%)	2(6,5%)	0(0%)

Many pupils from both groups got no marks for questions 1(a) and (b). The expository group performed particularly badly on question 1(a) with a greater percentage of pupils than from the inquiry group falling in the 'no understanding' category. Very few pupils from either group, however, had a 'full understanding' of the content. The results obtained from this analysis indicate that the pupils in the inquiry group did not appear to reveal a better understanding of the questioned aspects of the circulatory system in comparison with the pupils in the expository group.

Table 9 below shows a comparison of how the two groups performed on questions 3(a) and (b).

In both the inquiry and expository groups pupils' responses to question 3(a) and 3(b) of the TOU (dealing with the differences in the thickness of the walls of atria and ventricles) are compared in terms of the number and percentage of pupils in each of the following categories:

- No understanding - if no relevant or correct statement is made: 0 marks allocated.
- Understand - if one or two relevant (and correct) statements are made: 1 - 2 marks allocated.

Table 9: *Number and percentage of pupils in each 'category of understanding' for questions 3(a) and (b) of the TOU*

	Extent of understanding			
Question	Do not Understand (0 marks)		Understand (1 - 2 marks)	
	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)	Number of pupils Inquiry (n=31)	Number of pupils Expository (n=26)
3(a)	27(87,1%)	22(84,6%)	4(12,9%)	4(15,4%)
3(b)	27(87,1%)	22(84,6%)	4(12,9%)	4(15,4%)

The majority of pupils in both groups have not shown the expected level of understanding of the content. The expository group has a slightly lower percentage of pupils (2,5%) in the 'no understanding' category whilst they have a slightly higher percentage of pupils (2,5%) in the 'understand' category. Very few pupils from either group had an understanding of the content required in questions 3(a) and (b). The pupils taught using inquiry methods did not seem to demonstrate a greater understanding of the questioned aspects of the circulatory system than the pupils taught by more traditional expository methods.

It thus appears that the inquiry package used in this study did not result in a better understanding of the circulatory system by the pupils using this method of learning.

4.2 ATTITUDES TOWARDS SCHOOL BIOLOGY

The *Attitude Towards School Biology Test* was used to measure how pupils feel towards biology as a school subject. It was administered as a pre- and posttest to both the inquiry and expository groups. Table 10 below shows the changes in mean scores between the pre- and posttests for both the inquiry and expository groups.

Table 10: *Descriptive statistics of inquiry and expository group results on the Attitude Towards School Biology Test (both pre- and posttest)*

	Inquiry group	Expository group
	Pretest (n = 34)	*Pretest (n = 29)*
Mean score	51,6	48,4
Standard deviation	11,17	8,87
Cronbach Alpha Reliability	0,96	0,91
	Posttest (n = 35)	*Posttest (n = 28)*
Mean score	52,9	49,6
Standard deviation	9,9	8,2
Cronbach Alpha Reliability	0,92	0,95

Slight improvements in attitudes (as reflected by mean scores) for both groups are observable in terms of pre- and posttest comparisons. The inquiry group mean score increased by 1,3 whilst the expository group mean score increased by 1,2. The inquiry group posttest mean score is 3,3 higher than that of the expository group, but they had higher attitude scores prior to the intervention. It would thus seem as if the inquiry group did not develop more favourable attitudes than the expository group after having worked through the inquiry package.

An analysis of covariance was done to determine whether the difference in posttest scores of the experimental and expository groups were statistically significant or not, after pretest differences had been taken into account. The pretest scores were used as covariates to compensate for initial attitudinal differences between the groups. The results are shown in Table 11.

Table 11: *Analysis of covariance of posttest scores of the experimental and expository groups on the Attitude Towards School Biology Test (using pretest scores as covariates)*

Source	Degrees of freedom	Sum of squares	Mean square	F value
Group	1	169,0567	169,056	
Test	1	2,2067	2,2067	
Group x test	1	26,0159	26,0159	0,28

Analysis of covariance of posttest scores on the *Attitude Towards School Biology Test* reveals no significant differences between the inquiry and expository groups at the 0,05 level of significance, once the pretest scores have been taken into account. The teaching and learning of the circulatory system by inquiry (as used in this study) did not result in more favourable pupil attitudes towards biology compared to the attitudes of pupils in the expository group.

Although the mean attitude scores did not reveal any differences, it was decided to look at the distribution of scores within particular mark ranges. The results are shown in Table 12.

Table 12: *Number and percentage of pupils scoring in particular mark ranges on the Attitude Towards School Biology Test (pre- and posttest)*

Mark range	Number of pupils			
	Inquiry group		Expository group	
	Pretest (n=34)	Posttest (n=35)	Pretest (n=29)	Posttest (n=28)
14-21	2(5,8%)	1(2,8%)	0(0%)	0(0%)
22-28	0(0%)	0(0%)	0(0%)	1(3,5%)
29-35	0(0%)	0(0%)	2(6,8%)	1(3,5%)
36-42	1(2,9%)	4(11,4%)	8(27,5%)	2(7,1%)
43-49	9(26,4%)	8(22,8%)	3(10,3%)	6(21,4%)
50-56	12(35,2%)	13(37,1%)	9(31%)	13(46,4%)
57-63	6(17,6%)	6(17,1%)	6(20,6%)	5(17,8%)
64-70	4(11,7%)	3(8,5%)	1(3,4%)	0(0%)

There are generally only slight changes in the percentages of pupils in the two group scoring within particular mark ranges between pre- and posttest scores. It is of cours not possible to determine whether it is the <u>same</u> pupils scoring within particular mark ranges in the pre- and posttests. Figures 3 and 4 provide a visual impression of the comparative distributions of scores of the two groups.

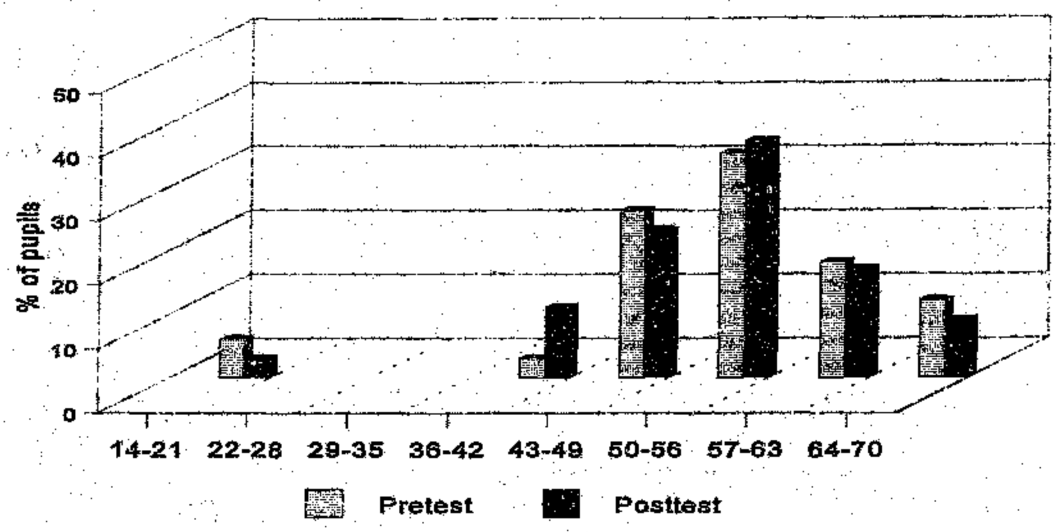


Figure 3: *Comparative bar chart of pre- and posttest scores within specific mark ranges for the inquiry group on the Attitude Towards School Biology Test*

Figure 3 shows a drop in the percentage of pupils in the lowest mark range based on a comparison of pre- and posttest scores. There seem to be a smaller percentage of pupils with 'negative' attitudes and a slightly larger percentage of pupils with more favourable attitudes (this is also shown by the slight increase in posttest mean score for the inquiry group). There is, however, a lower percentage of pupils in the high scoring categories. This trend is reflected by the lower standard deviation of posttest scores of the inquiry pupils compared to the pretest scores. There is thus a more homogenous distribution of posttest scores around the mean. It is, however, apparent that there was not much difference in pupils' attitudes towards biology after completing the inquiry package. These results were disappointing as the researcher expected the inquiry pupils to develop more favourable attitudes. Perhaps the intervention period was too short to result in attitudinal changes. It may also be that the looming end-of-year examinations influenced the pupils' attitudes in a negative way.

Similar to Figure 3, Figure 4 below shows the percentage of pupils in mark ranges but for the expository group, based on pre- and posttest scores.

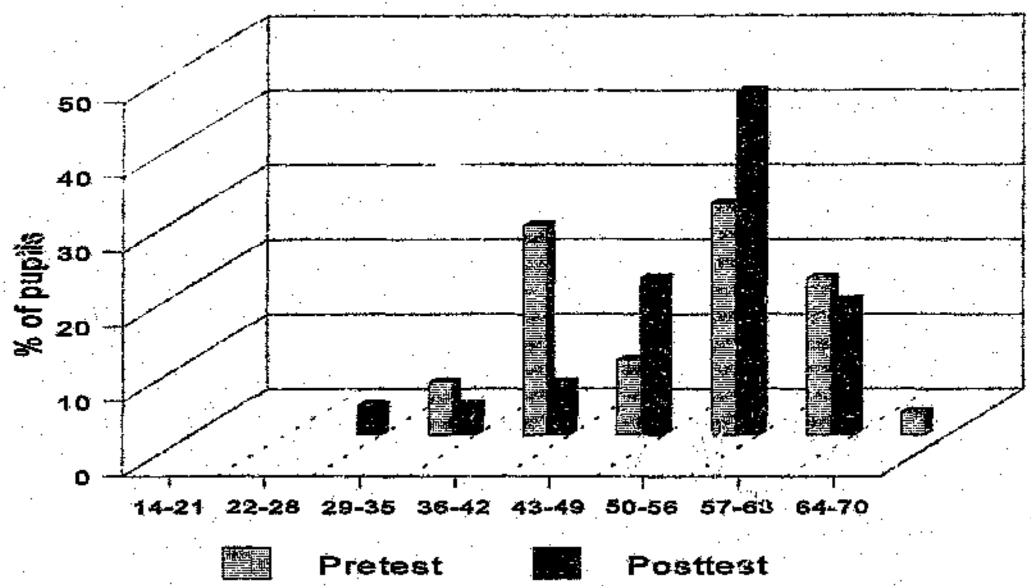


Figure 4: *Comparative bar chart of pre- and posttest scores (within specific mark ranges) for the expository group on the Attitude Towards School Biology Test*

The bar chart indicates a drop in the percentage of pupils with posttest scores in the low mark ranges (which are associated with negative attitudes) and an increase in the percentage of pupils with posttest scores in the higher mark ranges (which indicate more positive attitudes). There are, however, no posttest scores in the highest mark range so that the mean score for the group improved only slightly. The bar chart also shows that the posttest scores are more homogenously scattered as is also reflected by the lower standard deviation score for the posttest. Perhaps the section on the heart is an interesting one, no matter how it is taught.

Item analysis of Attitude Towards School Biology Test

Studies by Johnson (1976), Mason and Kahle (1988) and Ajewole (1991) have shown that many of the students they investigated found inquiry orientated classes to be more enjoyable than expository orientated classes. Three items from the *Attitude Towards School Biology Test* that are thought to be closely related to the "enjoyment" aspects of the inquiry teaching package were selected. They are items 3, 6 and 8.

Item 3 - During biology class, I usually am interested

Item 6 - Biology is interesting to me and I enjoy it

Item 8 - Biology is fascinating and fun.

For the purpose of the item analysis pupils' responses were categorised into positive (if they agreed or strongly agreed with the item statement), neutral (if they neither agreed nor disagreed), and negative (if they disagreed or strongly disagreed). The results are shown in the table below.

Table 13: Item analysis of selected items of the Attitude Towards School Biology Test

Item	Inquiry group Pretest (n = 35) Number of responses			Expository group Pretest (n = 29) Number of responses		
	Positive	Neutral	Negative	Positive	Neutral	Negative
3	20	9	6	11	13	5
6	27	7	1	19	8	2
8	21	13	1	16	10	3
	68	29	8	46	31	10
	Posttest (n = 34) Number of responses			Posttest (n = 28) Number of responses		
3	20	10	4	14	8	6
6	29	3	2	20	7	1
8	28	5	1	18	7	3
	77	18	7	52	22	10

The inquiry group as well as the expository group showed an increase in the total number of 'positive' responses from the pretest to the posttest for the three items combined. It would thus seem as if the decrease in the total number of 'neutral' responses in the two groups was due to more of the pupils responding positively in the posttest.

The expository group, however, had fewer positive responses to the three items combined than the inquiry group after the intervention period. In order to check whether significantly more pupils who experienced the inquiry package find biology interesting and more enjoyable than pupils who had experienced expository teaching, a Chi-square test was used.

The Chi-square test was used to determine whether the differences between the obtained frequencies (posttest scores) and expected frequencies (pretest scores) for each of the two groups are significant or not. Separate contingency tables were set up for each of the three items (3, 6 and 8). The results are shown in Table 14.

Table 14: *Expected and obtained frequencies of responses to Items 3, 6 and 8 for inquiry and expository groups*

Nature of response		Inquiry group		Expository group	
		Expected frequency (pretest)	Obtained frequency (posttest)	Expected frequency (pretest)	Obtained frequency (posttest)
ITEM 3	Positive	20	20	14	11
	Neutral	10	9	8	13
	Negative	4	6	6	5
ITEM 6	Positive	29	27	20	19
	Neutral	3	7	7	8
	Negative	2	1	1	2
ITEM 8	Positive	28	21	18	16
	Neutral	5	13	7	10
	Negative	1	1	3	3

The sum of the chi-square (χ^2) of the cells of the table for item 8 yields a value of 8,4 which at 2 degrees of freedom is significant at the 0,01 level of significance. This would indicate that there is a less than 1% probability that the difference in association between group and response is due to chance. It may thus be that the inquiry package has caused an increase in positive responses by pupils in the inqu'y group to the statement that "Biology is fascinating and fun".

The sum of chi-square of the cells of the tables for items 3 and 6 yields values of 3,53 and 4,11 respectively which at 2 degrees of freedom is not significant at the 0,05 level of significance. This indicates that there is a greater than 5% probability of an association between the two groups and the type of response to items 3 and 6 being due to chance. It can therefore not be said that the inquiry package resulted in pupils in the inquiry group being "more interested in class" or finding biology more "interesting and enjoyable" than the pupils in the expository group.

The results of this study thus fail to show a significant difference in attitudes of pupils in the inquiry group and the expository group towards biology as a school subject. There is, however, an indication that perhaps the inquiry package may have caused pupils in the sample to find biology more "fascinating and fun".

4.3 FEEDBACK FROM THE TEACHER

Cohen and Holiday (1982) contend that what might be statistically significant may be of no educational significance and conversely that what might not be statistically significant may well have educational significance. The feedback obtained from the teacher is regarded as important as it is considered by this researcher as having "educational significance" despite the statistically non-significant results obtained in this study.

A full evaluation of the lessons of the teaching package by the teacher who taught them is included as *Appendix C* on page 120 . The main points made by the teacher (who taught both groups in this study) seem to be the fact that the inquiry pupils *"enjoyed the investigations, perhaps due to the novelty aspect"*. Although most pupils *"relished the idea of the 'hands-on' activities, some pupils were 'squeamish' and preferred to withdraw from the activities"*. The teacher, however, repeatedly commented after each lesson that the pupils *"generally enjoyed the investigations"*.

Another important aspect of the feedback from the teacher is the increased demands placed on the teacher in terms of supervision. Some of the activities in the lessons provided opportunity for "horseplay" (e.g. the "stethoscope" and "water pump" investigations). Pupils also needed help in handling the apparatus and specimens correctly. A verbal comment was made by the teacher in question that perhaps a laboratory assistant should be present at all times during "inquiry lessons" to *"keep an* *eye on the proceedings*" and to "*keep the trouble-makers at bay*".

Another issue raised was that pupils also tended to answer the inquiry worksheet questions superficially. The point was made that "*it seems as if pupils have difficulty in expressing themselves in describing what they see*". The teacher also reported that the pupils found it difficult to relate the answers to the information supplied, particularly when the information is in the form of a graph. The teacher suggested that some of the content is "*perhaps a little too abstract for most of the pupils*".

Overall, the teacher expressed the view that the series of lessons went off well and that the investigations were generally well enjoyed. He indicated that he would certainly use more inquiry learning in his own teaching in future.

Chapter 5 - Discussion and Conclusion

An attempt was made in this study to answer some questions related to the effectiveness of an inquiry approach to teacning and learning, specifically, whether an inquiry approach to the teaching of the human circulatory system to Standard Eight Biology pupils resulted in greater understanding and whether pupils taught by inquiry would develop more favourable attitudes towards Biology as a subject at school. Since this research is a small scale study it can in no way provide conclusive answers to the questions posed beyond the context of the case study conducted. The findings of this study may, however, serve as a basis for future studies in this field.

5.1 LIMITATIONS OF STUDY

Borg and Gall (1989) provide evidence of important weaknesses that often exist in educational research and point out the importance of such weaknesses being identified and acknowledged by researchers and reviewers alike in weighing research results. The following factors are probably shortcomings of the study reported:

- **<u>The sample</u>**

The sample used in this study was not obtained randomly and can not therefore be considered representative of the larger population. This makes the results obtained non-generalisable. The sample was also small which makes it more difficult to obtain results revealing significant differences (see discussion on page 56 in Chapter 4).

- **<u>The intervention period</u>**

The short intervention period also makes it difficult to get significant differences particularly in terms of changing pupils' attitudes. Researchers such as Mason and Kahle (1988) and Ajewole (1991) recommend long periods of intervention in order to bring about changes in attitudes. They do not, however, indicate <u>how long</u> the intervention should be. Some writers, notably Gogolin and Swartz (1992), support the view of the educational psychologist Gagné that attitudes can change in a short period of time. The three week intervention period used in this study may well not have been sufficiently long to bring about a change in pupils' attitudes.

- **The pilot study**

Another problematic issue in the study is that no specific steps were taken during the pilot testing of the testing instruments and of the inquiry package to gather data from the pupils about any problems they may have had. The pupils could have been asked to think more carefully about each instruction on the worksheet and every item in the tests and to then write down any problem they may have had. Perhaps more problems with instructions in the worksheets and questions in the tests would have come to light. The teacher involved in the pilot study was used as the only source of information as to problems with the instruments and the package. The teacher was instructed to question the pupils on whether they had any problems in understanding the instructions on the worksheets and questions in the tests. Minor problems emerged using this procedure. It may well be that other problems would have emerged if a more direct method was used to obtain information from the pupils.

- ***The attitude test***

A problem associated with using Likert scales in attitudes research is that they yield continuous scores which are then often analysed using statistical methods which are appropriate only for interval data. Kerlinger (1986) states that the use of these statistical methods on data obtained from Likert scales is a widely used research practice.

Also, concerning the attitude test, it can be argued that perhaps pupils' attitudes towards the mode of instruction itself should have been assessed rather than pupils' attitudes towards Biology as a subject at school. This may have been more appropriate in the context of this study.

Another issue regarded as a shortfall of the study is the fact that on the attitude test questionnaire pupils were not asked to indicate the grade on which they take Biology. It was also impossible to get this information from class lists as the pupils completed the attitude test anonymously. It would have been interesting to compare Higher and Standard Grade pupils' attitudes separately for the two groups as was done with the results of the *Test of Understanding*.

- **The Test of Understanding (TOU)**

The low scores achieved by the groups on the TOU indicate low levels of understanding of the circulatory system. The test was considered by this researcher and by the project supervisor to test understanding rather than factual recall that can be rote-learned. It may thus be that the test was too difficult for Standard Eight pupils and that they were not capable of demonstrating the level of understanding tested. This view, however, seems to be repudiated by the TOU results of the group used in the pilot study.

5.2 SUMMARY OF FINDINGS

In this section the findings of the two research questions that this study set out to answer are discussed.

5.2.1 Do Standard 8 Biology pupils taught by an inquiry teaching approach have a better understanding of the circulatory system than pupils taught by a traditional expository approach?

The results of this study indicate that the pupils taught by an inquiry teaching approach did not develop a better understanding of the circulatory system than pupils taught by the traditional expository approach. An analysis of covariance (ANCOVA) verified the view that the difference in mean scores for the two groups was not statistically significant.

During the analysis of the results it was decided to compare the results of the Higher and Standard Grade pupils in each group separately. The results indicate that the Higher Grade pupils in the inquiry group did not have a better understanding of the circulatory system than the Higher Grade pupils in the expository group. Analysis of covariance showed that the difference in mean scores of the two groups was not statistically significant. Similarly, the difference in mean scores of the Standard Grade pupils in the two groups proved not to be statistically significant.

An item analysis of pupils answers to selected questions from the test (thought by the researcher to test understanding rather than factual recall) showed that the inquiry package did not result in a better understanding of the circulatory system by the pupils in the sample used in this study.

This study has thus failed to show that the inquiry approach (as used in this study) to teaching the circulatory system to this particular sample of pupils resulted in a better understanding compared to the pupils that were taught using an expository approach.

5.2.2 Do Standard 8 Biology pupils receiving inquiry-orientated instruction develop more favourable attitudes towards Biology as a school subject than do pupils receiving expository instruction?

The results indicate that the pupils in the inquiry group did not develop more favourable attitudes towards biology as a school subject than the pupils in the expository group. Differences in mean scores between the two groups were found <u>not to be significant</u> by an analysis of covariance.

The item analysis of three of the items dealing with interest, fun and enjoyment from the attitude test revealed that both the inquiry and expository pupils had increasing numbers of positive responses to the items in the posttest. A Chi-square test revealed that the differences between the obtained frequencies of responses (posttest scores) and expected frequencies (pretest scores) for the three items combined were <u>not statistically significant</u>.

An analysis of the three items separately was conducted. A Chi-square test revealed a <u>significant difference</u> in the frequency of responses between the inquiry and expository groups to item 8, "Biology is fascinating and fun". However, the results for the other two items (items 3 and 6) showed <u>no significant differences</u> between the frequency of positive, neutral and negative responses between the inquiry and expository groups.

This study has thus failed to show that pupils receiving inquiry-orientated instruction develop more favourable attitudes towards biology as a school subject than pupils receiving expository instruction. However, there seems to be some evidence that perhaps the inquiry approach has resulted in more pupils in this sample finding biology fascinating and fun.

5.3 SUGGESTIONS FOR FURTHER INVESTIGATIONS

It is suggested that more studies be conducted on teaching by inquiry, perhaps with larger samples, longer intervention periods and with better control of extraneous variables. It is further suggested that a qualitative study be included in further studies into inquiry learning as valuable information may emerge from observations of pupils at work in inquiry classrooms. Such studies may shed light on the equivocal research findings which abound in the literature describing quantitative studies into inquiry learning.

REFERENCES

AJEWOLE, G.A. (1991). Effects of discovery and expository instructional methods on the attitude of students to biology. **Journal of Research in Science Teaching,** 28(5): 401-409.

ALLPORT, G.W. (1935). 'Attitudes' In Murchinson, C. (Ed), **Handbook of Social Psychology**. Worcester, Mass: Clark University Press.

ANDERSON, R. (1983). Are yesterday's goals adequate for tomorrow? **Science Education,** *67*(2): 171-176.

ATKINSON, P. and DELAMONT, S. (1977). Mock-ups and cock-ups: the stage-management of guided discovery instruction. In **School Experience in the Sociology of Education.** Edited by Woods, P. and Hammersly, M. London: Croom Helm.

AUSTOKER, J. and WESSELS, H.J. (1987). **Biology for Today Standard Eight.** Johannesburg: Juta and Co, Ltd.

BAILEY, M., HIRST, K. and WATKIN, R. (1989). **Active Biology: Teacher's Handbook**. London: Hodder and Stoughton.

BENNETTS, J., BURDETT, P., WALTERS, P. and WILLIAMS, A. (1989). **Science Skills. Problems in GCSE Biology**. London: Hodder and Stoughton.

BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS) (1963). **Biological science. An inquiry into life**. New York: Harcourt, Brace and World, INC.

BORG, W.R. and GALL, M.D. (1989). **Educational Research: An Introduction, Fifth Edition**. New York and London: Longman.

BRODDERMAN, A. (1985). The influence of activity-based elementary science programs on classroom practices: a quantitative synthesis. **Journal of Research in Science Teaching**, 21(15): 289-303.

CARIN, A. and SUND, R. (1980). **Teaching science through discovery**. Columbus: Charles E. Merril Publishing Company.

COHEN, L. and HOLLIDAY, M. (1982). **Statistics For Social Scientists.** London: Harper and Row.

COOK, T.D. and CAMPBELL, D.T. (1979). **Quasi-Experimentation. Design and analysis issues for field settings**. Boston, Geneva, Hopewell and London: Houghton Miflin Company.

COSTENSON, K. and LAWSON, A. (1986). Why isn't inquiry used more in classrooms? **The American Biology Teacher**, 48(3): 150-158.

CROCKER, R.T., BARTLETT, K.R. and ELLIOT, H.G. (1976). A comparison of structured and unstructured modes of teaching science process activities. **Journal of Research in Science Teaching**, 13(3): 267-274.

DELANEY, J. (1980). **A comparison between individualised instruction and traditional teaching methods in elementary grades in American public schools**. Pretoria: Unpublished D.Ed. thesis, UNISA.

DRIVER, R. and BELL, B. (1986). Student's thinking and the learning of science: a constructivist view. **The School Science Review**, 67(240): 443-456.

DRIVER, R., GUESNE, E. and TIBERGHIEN, A. (1985). **Children's ideas in science**. Milton Keynes: Open University Press.

EGELSTON, J. (1973). Inductive vs traditional methods of teaching high school biology laboratory experiments. **Science Education**, 57(4): 467-477.

FALK, D. (1980). **Biology teaching methods**. New York: Robert E. Krieger.

FISHER, K. and LIPSON, J. (1986). Twenty questions about student errors. **Journal of Research in Science Teaching**, 23(9): 783-803.

GALLAGHER, J. and YAGER, R. (1980). Perceived problems of science educators for their discipline. **Science Education**, 64(5): 725-728.

GERMANN, P.J. (1988). Development of the Attitude Towards Science in School Assessment and its use to investigate the relationship between science achievement and attitude towards science in school. **Journal of Research in Science Teaching**, 25(8): 689-703.

GOGOLIN, L. and SWARTZ, F. (1992). A quantitative and qualitative inquiry into the attitudes towards science of non-science college students. **Journal of Research in Science Teaching**, 29(5): 487-504.

GOULD, C. (1982). The scientific attitude and science education: a critical reappraisal. **Science Education**, 66(1): 109-121.

GOULD, C. (1983). Biology teaching: is there another way? **The School Science Review**, 65(231): 373-377.

HALADYNA, T., OLSEN, R. and SHAUGHNESSY, J. (1982). Relations of student teacher and learning environment variables to attitude towards science. **Science Education**, 66(7): 671-687.

HALL, D.A. and McCURDY, D.W. (1990). A comparison of a Biological Sciences Curriculum Study (BSCS) laboratory and traditional laboratory on student achievement at two private liberal arts colleges. **Journal of Research in Science Teaching**, 27(7): 625-636.

HEAD, J. (1982). What can psychology contribute to science education? **The School Science Review**, 63(225): 631-642.

HITCHCOCK, D. (1993). Misconceptions of primary science teachers. Proceedings of the first annual meeting of SAARMSE (South African Association for Research in Science and Mathematics Education). 28-31 January. Grahamstown: Rhodes University.

HOWARD, R. (1989). What is 'understanding' in science teaching and how can it be promoted? **The School Science Review**, 70(252): 117-119.

HURD, P. (1978). The teaching of biology: a possible future. **Biological Sciences Curriculum Studies Journal**, 1(4): 20-26.

HURD, P. (1980). Biology education in secondary schools of the United States. **The American Biology Teacher**, 42(7): 388-410.

HSRC (1981). Teaching of the natural sciences and mathematics. Report 12 of the investigation into education. Pretoria: Human Sciences Research Council.

ISAAC, T. (1993). The influence of the Senior Certificate examination on methods of teaching biology at standard ten level in Indian secondary schools. Proceedings of the First Annual Meeting of the South African Association for Research in Mathematics and Science Education. 28-31 January. Rhodes University, Grahamstown: 66-77.

JOHNSON, R. (1976). The relationship between co-operation and inquiry in science classrooms. **Journal of Research in Science Teaching**, 13(1): 55-63.

JOHNSON, R., RYAN, F. and SCHROEDER, H. (1974). Inquiry and the development of positive attitudes. **Science Education**, 58(1): 51-56.

JOHNSTONE, A. (1986). Connections and misconceptions in science. **Spectrum**, 24(3): 60-64.

KEEGAN, M. (1993). Optimizing the instructional moment: A guide to using Socratic, Didactic, Inquiry, and Discovery methods. **Educational Technology**, 33(4): 17-22.

KERLINGER, F.N. (1986). **Foundations of behavioral research**. New York: CBS Publishing, Ltd.

KRYNOWSKY, B.A. (1988). Problems in assessing student attitude in science education: a partial solution. **Science Education**, 72(5): 575-584.

LOCK, R. (1994). Nuffield advanced biology naff? No, not even after 26 years. **Journal of Biological Education**, 28(3): 191-194.

MASON, C.L. and KAHLE, J.B. (1988). Student attitudes towards science and science related careers: a program designed to promote a stimulating gender-free learning environment. **Journal of Research in Science Teaching**, 26(1): 25-39.

McCORMACK, A. and YAGER, R. (1989). A new taxmomy of science education. **The Science Teacher**, 72(2): 47-48.

MECH, I.C.E. (1990). A comparitive study of the inquiry and illustrative approaches to the teaching of microscope skills. Unpublished M.Ed. research report. Johannesburg: University of the Wiwatersrand.

MILLS, I. (1977). Factors, frameworks and flavourings: an alternative to praxis? **British Journal of Educational Studies**, 25(2): 5-10.

MULOPO, M. and FOWLER, H. (1987). Effects of traditional and discovery instructional approaches on learning attitudes for learners of different intellectual development: A study of students in Zambia. **Journal of Research in Science Teaching**, 24(3): 217-227.

MUNBY, H. (1983). Thirty studies involving the 'Scientific Attitude Inventory': What confidence can we have in this instrument? **Journal of Research in Science Teaching**, 20(2): 141-162.

NOVAK, J.D. (1970). **The improvement of biology teaching**. New York: Bobbs-Merril.

NOVAK, J. (1984). Application of advances in learning theory and philosophy of science to the improvement of chemistry teaching. **Journal of Chemical Education**, 61(7): 607-612.

O'LOUGHLIN, M. (1992). Rethinking science education: beyond Piagetian constructivism towards a sociocultural model of teaching and learning. **Journal of Research in Science Teaching**, 29(8): 791-820.

PUGLIESE, A.C. (1973). The meaning of inquiry, discovery and investigative approaches to science teaching. **The Science Teacher**, 40(1): 24-27

RODRIGUEZ, I. (1983). An inquiry approach to science and language teaching. **Journal of Research in Science Teaching**, 20(4): 291-296.

SCHIBECI, R.A. (1984). Attitudes to science: an update. **Studies in Science Education**, 11(6): 26-59.

SCHWAB, J.J. (1964). Structure of the disciplines: meanings and significances. In Ford, G.W. and Pagas, L. (Ed). **The structure of knowledge and the curriculum**. Chicago: Rand MacNally.

SELIM, M. and SHRIGLEY, R. (1983). The group dynamics approach: A socio-psychological approach for testing the effect of discovery and expository teaching on the science achievement and attitude of young Egyptian students. **Journal of Research in Science Teaching**, 20(3): 213-224.

SHYMANSKY, J.A., HEDGES, L.V. and WOODWORTH, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. **Journal of Research in Science Teaching**, 27(2): 127-144.

SIMPSON, R.D. and TROOST, K.M. (1982). Influences on commitment to and learning of science among adolescent students. **Science Education**, 66(5): 763-781.

SUMMERS, M. (1982). Science education and meaningful learning. **The School Science Review**, 64(227): 361-366.

SUND, R.B. and TROWBRIDGE, L.W. (1973). **Teaching science by inquiry in the secondary school**, 2nd edition. Columbus, Ohio: Charles E. Merill.

TAMIR, P. (1975). Nurturing the practical mode in schools. **The School Science Review**, 83(3): 499-506.

TAMIR, P. (1983). Inquiry and the science teacher. **Science Education**, 67(5): 657-672.

TOWSE, P.J. (1983). Do new science courses improve attitudes towards science? A case study in Lesotho. **Science Education**, 67(2): 159-160.

VOSS, B.E. and BROWN, S.B. (1968). **Biology as inquiry**. St. Louis: Mosby.

WAREING, C. (1990). A survey of antecedents of attitudes towards science. **Journal of Research in Science Teaching**, 27(4): 371-386.

WELCH, W., KLOPFER, L. AIKENHEAD, G. and ROBINSON, J. (1981). The role of inquiry in science education: analysis and recommendations. **Science Education**, 65(1): 33-50.

WELLINGTON, J. (1981). "What's supposed to happen, sir?" Some problems with discovery learning. **The School Science Review**, 63(222): 167-173.

WIDEEN, L. (1975). Comparison of student outcomes for science - a process approach and traditional science teaching for third, fourth, fifth and sixth grade classes: A product evaluation. **Journal of Research in Science Teaching**, 12(1): 31-39.

WILSON, J. (1974). Processes of scientific inquiry: A model for teaching and learning science. **Science Education**, 58(1): 127-133.

YAGER, E.R. and PENICK, E.J. (1984). What students say about science teaching and science teachers. **Science Education**, 68(2): 143-152.

Lesson 1

An introduction to the circulatory system

Purpose of this lesson

The purpose of this lesson is to stimulate interest in the circulatory system. It is hoped that the questions on the historical background will get pupils to think critically about early hypotheses on circulation, and to become aware of the functioning of their own blood system. The purpose of INVESTIGATION 1 (observing Daphnia under microscope) is to give pupils an opportunity to see a living heart in action and make observations and deductions regarding the rate of heartbeat.

Requirements

- **sufficient Daphnia in glass jar for each group (2 - 3 Daphnia per group)**
- **one large and one small glass jar per group**
- **bunsen burner and tripod stand per group**
- **crushed ice (at least four groups will need ice)**
- **depression microscope slides, threads of cotton and coverslips**
- **one thermometer per group**
- **mono/binocular electric microscopes**
- **graph paper (one sheet per pupil)**
- **Worksheet 1 - Introduction to the circulatory system (one per pupil)**

Suggested approach

- **It is suggested that pupils work in groups of two or three at their "lesson seats" and work through pages 1 and 2 of the worksheet before going to their "practical work benches" - allow 10-15 minutes for the answering of the questions on page 1 and 2.**
- **Pupils should have ± 30 minutes to complete INVESTIGATION 1, working in groups of ± 4 at their work benches.**

- The teacher is to allocate the temperature of the waterbath that each group must prepare (each group works at one specific temperature i.e. one of 0°, 5°, 10°, 15°, 20°, 25°, 30° and 35°C).
- Ensure that pupils get the results from the other groups at the end of INVESTIGATION 1 to complete the data table and plot the graph (once every group has determined the average heart rate, the teacher should collate the readings and put them onto an overhead transparency so that pupils can complete their data table).
- Pupils should be encouraged to discuss observations made and to debate questions that may arise as they do the experiment.
- It is suggested that the teacher answers pupils' questions with responses that would stimulate further thought and allow the pupils to "discover the answers for themselves". However, it is important that pupils be helped with questions regarding whay they have to do, and how they must do it. This approach is to be followed throughout the series of lessons.
- Answering the questions and the plotting of the graph must be completed at home if there is not sufficient time in class.
- The teacher should encourage pupils to start working on their assignment as soon as possible and emphasise that it is to be turned in within 2 weeks.

Worksheet 1 - An introduction to the circulatory system

Recorded human intellectual history goes back at least 5 000 years. During the first 4 700 of these years some of the most important facts about the body, including the blood circulatory system, were unknown. This is not surprising, for if you think of your own body, you will see that it is almost impossible to guess what is happening inside it. You can feel your heart beat and can also feel your pulse. You can see and feel that your skin is sometimes pale and cold, sometimes hot and flushed.

What do these observations suggest is happening to the blood within your body from time to time?

Early scientists from ancient times had various hypotheses (unproved explanations) about blood. Aristotle believed that blood was formed in the liver. From there, it would flow to the heart. Then it would flow through the blood vessels to all parts of the body. The liver would then make more blood and the process would be repeated continually.

Give a reason why Aristotle's hypothesis would not work.

As a result of observations of the hearts of various animals, William Harvey, an English scientist of the seventeenth century, came to realise that the heart is a pump and that it continuously pumps out a large quantity of blood.

This finding enabled Harvey to make a brilliant deduction that would overcome the problem with Aristotle's hypothesis.

What do you think the deduction was?

....

....

....

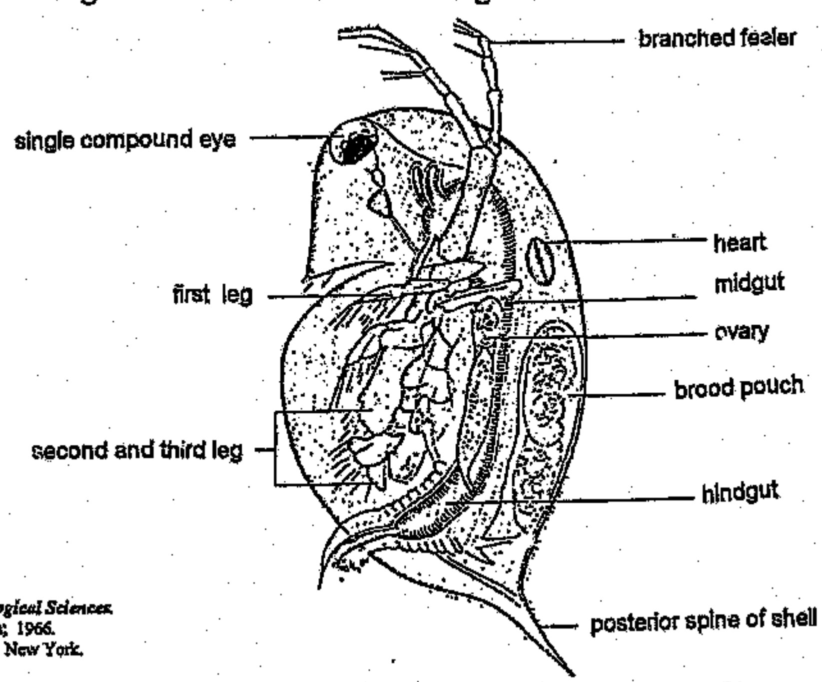
....

....

• INVESTIGATION 1

William Harvey realised that a great deal could be learned about the action of the human heart by studying the hearts of other kinds of animals.

In this investigation you can study the working heart of a living water flea, Daphnia. This organism is commonly found in freshwater ponds and lakes. It is so transparent that when placed under the low power of a microscope, its beating heart can be seen. See the diagram below to determine the location of the heart:

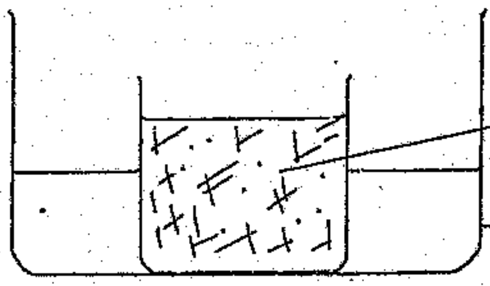


Source: *A sourcebook for the Biological Sciences.* Morholt, Brandwein, Joseph; 1966. Harcourt Brace Jovanovich. New York.

<u>The aim of this investigation is to determine if the rate of heartbeat (i.e. the number of beats per unit of time) is influenced by temperature.</u>

<u>Procedure:</u> Each group will work with <u>Daphnia</u> that will be placed in water at a <u>different</u> specific temperature. 0°, 5°, 10°, 15°, 20°, 25°, 30° or 35°C. Make sure that your teacher has informed your group as to the temperature of the water bath your group must prepare.

- Partially fill a large beaker with water and heat it, or if necessary, add ice, to bring it to the desired temperature. Monitor the temperature reading all the time (using your thermometer) and keep the temperature constant.
- Place a 50 ml beaker containing a few Daphnia in pond water in the large water bath beaker.



- Daphnia should be left in the water at that particular temperature for at least 10 minutes. Why do you think this is necessary?

....

The temperature of the water bath should not vary more than 1 or 2°C during the period in which Daphnia are in the water bath.

Determine the rate of the heartbeat as follows:

- Place a clean depression microscope slide into the water bath (To warm it up/cool it down).
- Using the medicine dropper put a few drops of water from the smaller beaker (containing Daphnia) onto the slide.
- Add two or three short threads of cotton fibre to the drop of water to avoid crushing Daphnia when you cover the specimen with a glass coverslip.
- Cover the drop with a coverslip (You should perform this experiment quickly so that the temperature changes as little as possible).
- Place the slide on the stage of the microscope and bring the heart into focus *(refer to diagram on page 2)*.
- Count the heartbeats during a 15 second interval and multiply by four to get the number per minute. The heartbeats are usually very fast. The following method will help you to count these beats:

  Place a pencil dot on a piece of paper for each beat of the heart.

  When the 15 second interval is over, count the dots.

- Repeat this procedure at least three times with the same flea and at the same temperature. Calculate the heartbeats per minute and take the average of your three trials. Record this average heartbeat per minute on your data table, for the temperature used by your group.

DATA TABLE

TEMPERATURE	AVERAGE heart rate per minute
0°C	
5°C	
10°C	
15°C	
20°C	
25°C	
30°C	
35°C	

At the end of the lesson your teacher will consolidate all the results from the other groups for you to complete your data table.

Using graph paper, draw a graph to show your results. Temperature should be plotted along the horizontal x-axis and heartbeat rate along the vertical y-axis.

HOMEWORK

ANSWER THE FOLLOWING QUESTIONS:

1. At what temperature is the heart rate the slowest?

....

2. At what temperature is the heart rate the fastest?

....

3. What is the effect of temperature on the rate of heartbeat of Daphnia?

....

....

4. What would happen to the heart rate if you continued to increase the temperature in 5°C intervals?

....

....

....

Your graph shows the experimental heart rates taken by different students using different Daphnia.

5. How accurate a plot is this? Explain your answer.

....

....

ASSIGNMENT: Coronary thrombosis

This assignment is due at the end of this section of the syllabus on the circulatory system.
Due date: ....

You must write a few paragraphs (1-2 pages) on coronary thrombosis including:

- what type of disease it is
- the causes
- possible effects of the disease
- how can it be prevented, and
- what doctors may decide to do after diagnosing a severe case of the disease.

Consult books in the school library and/or other sources for the information. List the resources used in the form of a bibliography.

Lesson 2

Examination of mammalian heart

Purpose of this lesson

The purpose of this lesson is to allow pupils to examine a mammalian heart (externally and internally) in order to become familiar with it's structure (chambers, valves, attached vessels, etc.) and to relate structure to function.

Requirements

- **one ox heart per group (arrange with abattoir to have hearts as intact as possible - with atria and blood vessels unscathed)**
- **one length (± 40 cm) of rubber tubing per group**
- **one metal clamp per group**
- **two scalpels, one pair of scissors and two dissecting needles per group**
- **one dissecting board per group**
- **one pair of surgical gloves per group (some pupils may prefer to use them)**
- **Worksheet 2 - Examination of the mammalian heart (one per pupil)**

Suggested approach

- **Pupils will need at least 50 minutes to complete INVESTIGATION 2.**
- **The teacher is to provide encouragement and support and must not give "direct answers" to questions pupils may ask them about the content. The teacher <u>must</u> however help the pupils with any questions related to the procedures to be followed.**

  In this regard: - the pupils may need your help in determining which is the ventral side of the heart (page 2 of Worksheet 1)

  - it is suggested that the teacher gets all the groups to start the internal examination (page 4 no. 5) simultaneously and to ensure that everyone understands the procedure.
- **Please alert pupils to the importance of completing the homework exercise as it deals with a number of issues not covered in the investigation.**

Worksheet 2 - Examination of the mammalian heart

- **INVESTIGATION 2**

Each group has been provided with an ox heart.

<u>External examination</u>

* Describe the general shape, colour, size and texture of the heart.

....

....

....

....

* What are the round, hollow cut off tubes attached to the top of the heart?.......................................

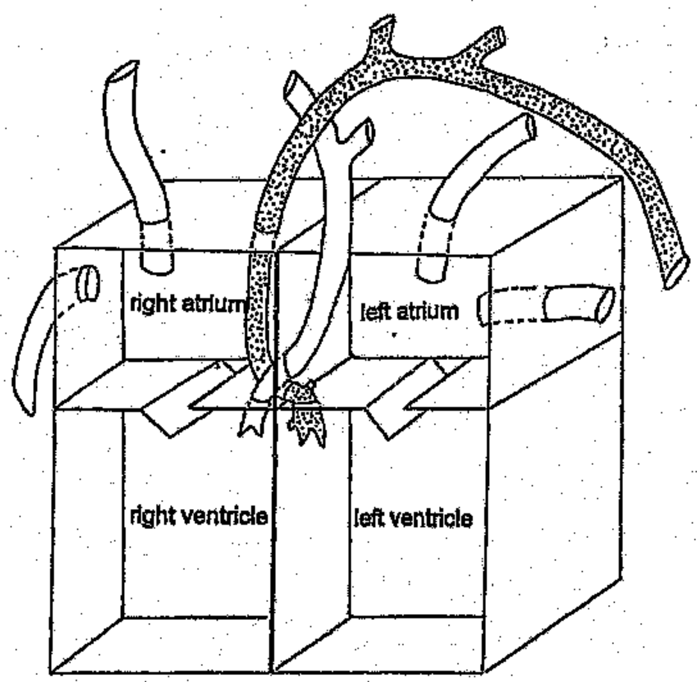
* Examine the walls of these hollow tubes. What do they feel like?

....

Are they all the same thickness?

....

Imagine the heart as a box with four chambers (such as in the diagram below). The left and right halves of the box are completely separated, but the two chambers in each half are connected by a door.



Refer to the "box heart" diagram on the previous page, as you read the following paragraph. Locate each structure mentioned.

> The mammal has a **double circulation**, that is, blood flows twice through the heart for every complete circuit of the body. **Deoxygenated** blood from the tissues enters the **right atrium** from the great veins (**venae cavae**). From the right atrium blood flows into the **right ventricle** from where it is pumped to the lungs via the **pulmonary artery**. Having been **oxygenated** in the lungs, blood is returned to the heart via the **pulmonary veins**; after entering the **left atrium** the blood flows into the **left ventricle** from where it is pumped to the body via the **aorta**.

Two main questions arise in connection with the heart: how is the blood propelled from it, and how is the blood kept moving in the right direction? Keep these questions in mind as you examine the ox heart.

1. Determine which is the dorsal and which is the ventral side of the heart. The ventral side of the heart is more rounded (convex) than the dorsal side, and the thick-walled arteries arise from this side. Hold the heart so that the blood vessels are at the top, and the ventral side is facing you (as in the diagram below). * *Please note that in humans the back of your body (spinal cord side) is called the dorsal side, and your front (chest and stomach side) is the ventral side. The same is true for a mammal such as an ox, except that it walks on four legs so that its dorsal side faces up, and the ventral side faces down.*

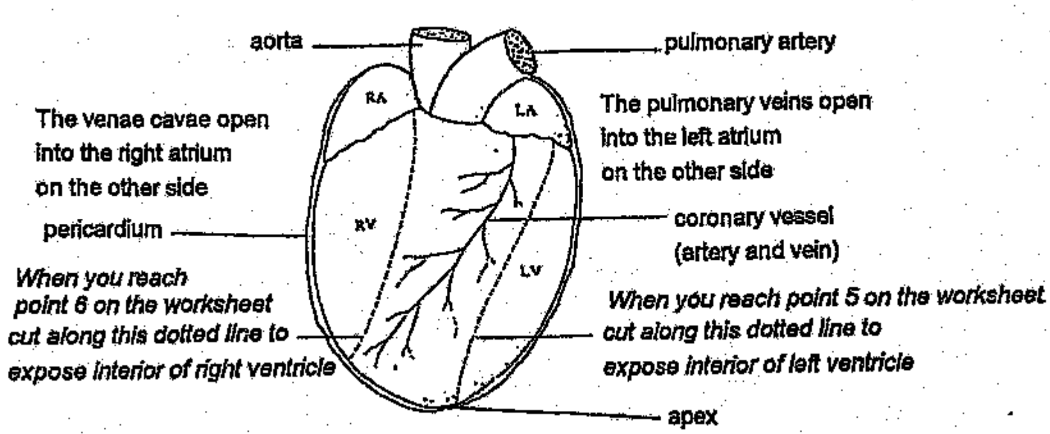


Figure 1 Ventral view of mammalian heart. This is the more convex side of the heart and shows the attachment of the aorta and pulmonary artery to the ventricles. The veins are on the dorsal side. RA, right atrium; LA, left atrium; RV, right ventricle; LV, left ventricle.

Source: *Biology a functional approach - Students Manual.* Roberts and King. 1987. Thomas Nelson & Sons Ltd. Surrey.

Why is it that the right atrium and ventricle is on your left-hand side, and the left atrium and ventricle is on your right-hand side as you look at the diagram?

....

....

....

....

2. Use the diagram (previous page) to help you find the following structures on your group's ox heart (as seen from the outside),

- the right and left atria,
- right and left ventricles,
- pulmonary artery (arises from the right ventricle),
- aorta (arising from the left ventricle),
- anterior and posterior venae cavae (opening into the right atrium) [NB: singular - *vena cava*; plural - *venae cavae*],
- pulmonary veins (opening into left atrium),
- pericardium (thin sac-like membrane surrounding the heart),
- coronary vessels (branching from aorta and entering heart wall) in heart wall.

Predict the function of the coronary vessels. Remember that the coronary vessels branch from the aorta (as it emerges from the heart) and enters the muscles of the heart wall.

....

....

....

....

3. The purpose of the next activity is to work out the passage of blood through the heart by observing the flow of water as it fills and runs through the chambers of the heart and emerges from it. Insert the end of a rubber tube leading from a tap, into the anterior vena cava. Clamp the posterior vena cava so that water won't leak out. Run water into the anterior vena cava and note its flow through the heart. From which blood vessel does the water emerge?..

Explain the movement of the water fully.

....

....

....

....

4. Now run water into the pulmonary vein and note the vessel from which it emerges. This is the aorta.

Internal examination

5. In order to see inside the left ventricle you must first cut it open. Position the heart so that the ventral side faces you. Now cut along the right-hand dotted line with a scalpel *(See figure 1 on page 2).* Cut from the bottom up, so as to expose the left ventricle.

   At the top of the ventricular cavity (on your left), observe the opening into the aorta guarded by a valve (known as a **semilunar** or **pocket valve**). To your right observe the atrioventricular opening guarded by the **bicuspid (mitral) valve.** Note that the bicuspid valve has two flaps attached to the ventricular wall by **tendinous chords** and **papillary muscles.** Find these structures. Pull the tendinous chords and see the effect on the valve. What do you think are the functions of the bicuspid valve and tendinous chords?

   ....

   ....

   ....

   ....

6. Slit open the right atrium and pulmonary artery (left-hand dotted line - *figure 1*) by continuing your ventricular slit upwards to the top of the heart. Observe the valves in detail as you did on the other side of the heart (note the **tricuspid valve** between the right atrium and right ventricle with its three flaps).

7. Examine the openings of the pulmonary veins into the left atrium and the openings of the venae cavae into the right atrium. Are there any valves guarding these openings and what might be their functions?

   ....

   ....

8. Finally, notice the relative sizes of the four chambers of the heart and the relative thickness of their walls. Which is the largest chamber .... and which one has the thickest wall?..

What do you think are the reasons for any differences you observed?

....

....

....

....

....

HOMEWORK

1a) Using your textbook for additional information, find out what initiates the contraction of the heart.

....

....

....

....

b) List in point form the phases involved in the contraction and expansion of the heart (the cardiac cycle).

....

....

....

....

....

....

....

....

....

c) List the structures through which blood flows in order to get from the venae cavae to the pulmonary artery.

....

....

d) Is the blood flowing from the venae cavae to the pulmonary artery oxygenated or deoxygenated?...

Explain your answer...

....

....

e) List the structures through which blood flows to get from the pulmonary veins to the aorta.

....

....

f) Is the blood flowing from the pulmonary veins to the aorta oxygenated or deoxygenated?..

Explain your answer..

....

....

2. Use arrows to indicate the direction of blood flow from the veins, through the heart and emerging in the arteries on the "box heart" diagram on page 1 of your worksheet.

Lesson 3

Consolidation of previous worksheets, listening to the sounds of the heart, and the effect of exercise on the heart rate

Purposes of this lesson

This lesson has three purposes:

- **to check the answers of the questions in Worksheets 1 and 2**
- **to give pupils the opportunity to listen to the sounds of their own hearts; and to feel their pulse in order to gain further understanding of the functioning of the circulatory system**
- **to have pupils examine the effects of exercise on the rate of the heartbeat.**

Requirements

- **1 or 2 stethoscopes per group**
- **stopwatches (pupils' wrist watches will do)**
- **Worksheet 3 - Sounds of the heart (one per pupil)**

Suggested approach

- **It is suggested that the first half of the double period be used to check that pupils have the appropriate answers to Worksheets 1 and 2.**
- **The remaining period should be used for pupils to complete INVESTIGATIONS 3 and 4.**
- **INVESTIGATION 4 may be completed by pupils for homework should there not be sufficient time in class. Also alert the pupils to the homework exercise at the end of the worksheet.**

Worksheet 3 - Sounds of the heart

- **INVESTIGATION 3**

Listening to the heart

Work in pairs, one person acting as the examiner and the other as the subject. The subject should sit down comfortably. The examiner is to place the earpieces of a stethoscope in his/her ears and put the bell against the chest wall of the subject just left of the breast bone in line with the arm pit. Listen to the sounds of the heart. Now reverse roles.

1. Do you hear the double sound of each beat?..

The sounds of the heart are caused by the shutting of the atrioventricular and the semilunar valves.

2. What do you think causes the first sound? Explain your answer.

....

....

....

What do you think causes the second sound? Explain your answer.

....

....

....

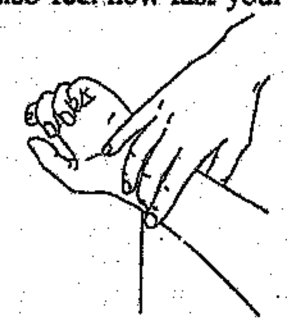
3. What kind of information do you think the doctor can get about a patient's heart by listening to it with a stethoscope?

....

....

....

You can also feel how fast your heart is beating by feeling your pulse. See the following diagram:



Now feel the pulse <u>and</u> listen to the heart sounds with the stethoscope at the same time.

Notice that there is a time lag between the heart sounds and the pulse.

Give a reason for this time lag.

....

....

....

What circumstances do you think may cause the time lag to be shorter?

....

....

From your observations try to calculate the speed at which your blood travels in cm per second.

....

....

• **INVESTIGATION 4** (This must be completed for homework if there is not sufficient time in class)

<u>To find the effect of exercise on the heart rate</u>

1. Measure your standing heart rate by feeling your pulse while standing. Write down your heart rate in beats per minute.

....

2. Do steady walking on the spot for three minutes.

3. Immediately after walking, measure your heart rate again. Write down your new heart rate in beats per minute.

………

How does it differ from the standing heart rate?

………

Explain the difference. (Remember that the cells of the body require oxygen to function)

………

………

………

4. Stand still and wait until your heart rate returns to its normal standing rate.

5. Work in pairs and decide which one of you will do some hard exercise for <u>three minutes</u>. The person doing the exercise, go down onto your haunches and stand up and down again etc.

6. Immediately after the exercise, measure your heart rate in beats per minute.

………

How does your heart rate immediately after the hard exercise differ from the standing rate?

………

Suggest a reason for the difference.

………

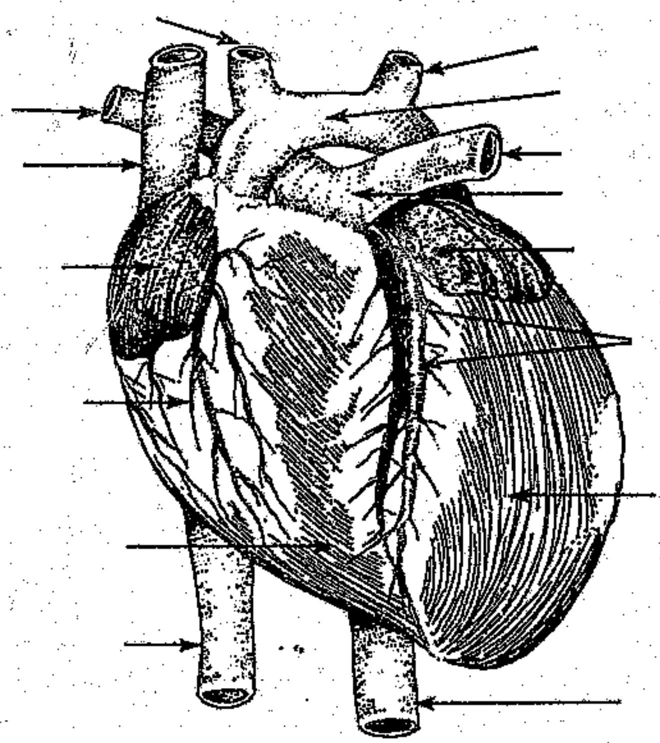
………

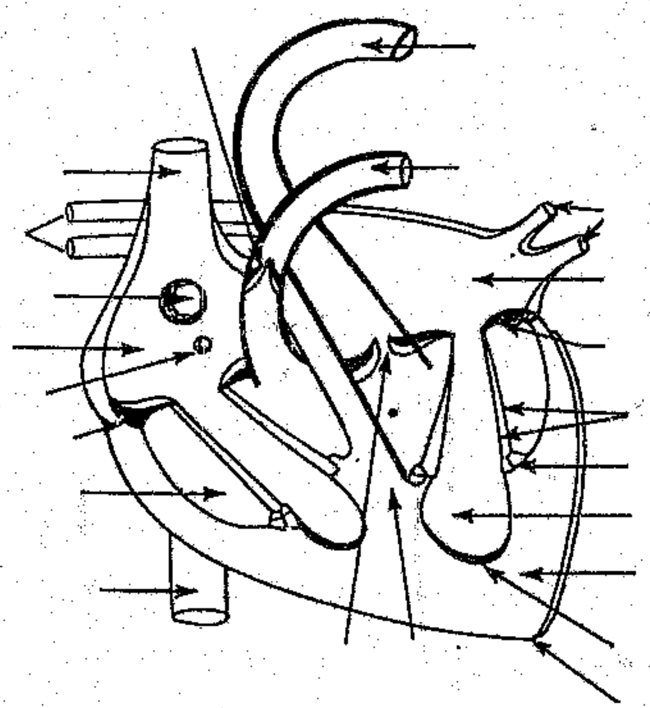
………

<u>HOMEWORK EXERCISE</u>

You have been given diagrams of the external and internal views of the heart as well as a list of labels for each. You are to cut out the labels and paste them correctly onto the diagrams.

(Arrange all labels before doing the pasting.)





Source: ***Biology for Today. Standard 8.***
Austoker and Wessels; 1986.
Juta & Co., Ltd. Johannesburg.

External view of mammalian heart.

left carotid artery

right ventricle

inferior vena cava

aorta

right carotid artery

left atrium

right coronary
vessels

aortic arch

right atrium

pulmonary artery

left coronary
artery and vein

left ventricle

right pulmonary
artery

superior vena cava

left pulmonary artery

Diagram of heart - longitudinal section.

position of pericardium

semilunar valves in
pulmonary artery

pulmonary artery

superior vena cava

coronary vein

tendinous chords

tendinous chords

inferior vena cava

semilunar valves
in aorta

papillary muscle

septum

left pulmonary veins

aortic arch

right pulmonary veins

left ventricle

right ventricle

endocardium

thick cardiac muscle
or myocardium of
left ventricle

left atrium

opening of inferior
(na cava

right atrium

part of tricuspid valve

mitral valve

Lesson 4

Heart muscle tissue/Veins and arteries

Purpose of this lesson

The purpose of this lesson is:

- to allow pupils to observe differences between heart muscle and skeletal muscle tissue and to make certain deductions
- to determine the differences in structure between arteries and veins
- to discover some of the structural and functional properties of veins (homework exercise - Harvey's experiment)
- to check answers to INVESTIGATIONS 3, 4 and 5.

Requirements

- bioviewer strip (Muscle tissue M9)
- 2 bioviewers per group
- Worksheet 4 (one per pupil)

Suggested approach

- Pupils are to start this lesson with a biostrip examination of muscle tissue.
- Pupils are to be encouraged to discuss their answers to the questions in their groups before writing them down.
- Use the last 20 minutes of the lesson to check the answers to INVESTIGATIONS 3, 4 and the homework exercise from lesson 3 and INVESTIGATION 5.
- Try to enthuse pupils about conducting Harvey's experiment (INVESTIGATION 6 for homework) and challenge them to see whether they can rediscover Harvey's findings.

Worksheet 4 - Biostrip examination of muscle tissue

- **INVESTIGATION 5**

1. Insert the biostrip (M9) into the bioviewer. Observe slides 1 and 3 carefully. Now <u>compare</u> slides 1 and 3 and write down the differences between skeletal and heart muscle tissue.

....

....

....

....

....

....

....

(Check that you have all the differences by referring back to the section on muscle tissue in your textbook.)

2. Study slide 4 showing Purkinje fibres between the other heart muscle fibres. The Purkinje fibres are a group of cells that makes up the **sino-atrial node** (SA node) that generates the electrical impulses for the contraction of the heart. Refer back to slide 3 and note the cross-connections (bridges) between the heart muscle (cardiac muscle) fibres. Suggest a possible purpose (function) for these cross-connections.

....

....

....

....

....

3. What was your standing heart rate? .... (Refer to INVESTIGATION 4). Now open and close your fist at that same rate for <u>two minutes</u>. Describe what the muscles in your hand feel like afterwards?

....

What does the above observation suggest about the way cardiac muscle differs from skeletal muscle?

4. Studies with an electron microscope show cardiac muscle to have many more mitochondria than any other body tissues. Why do you think there are so many?

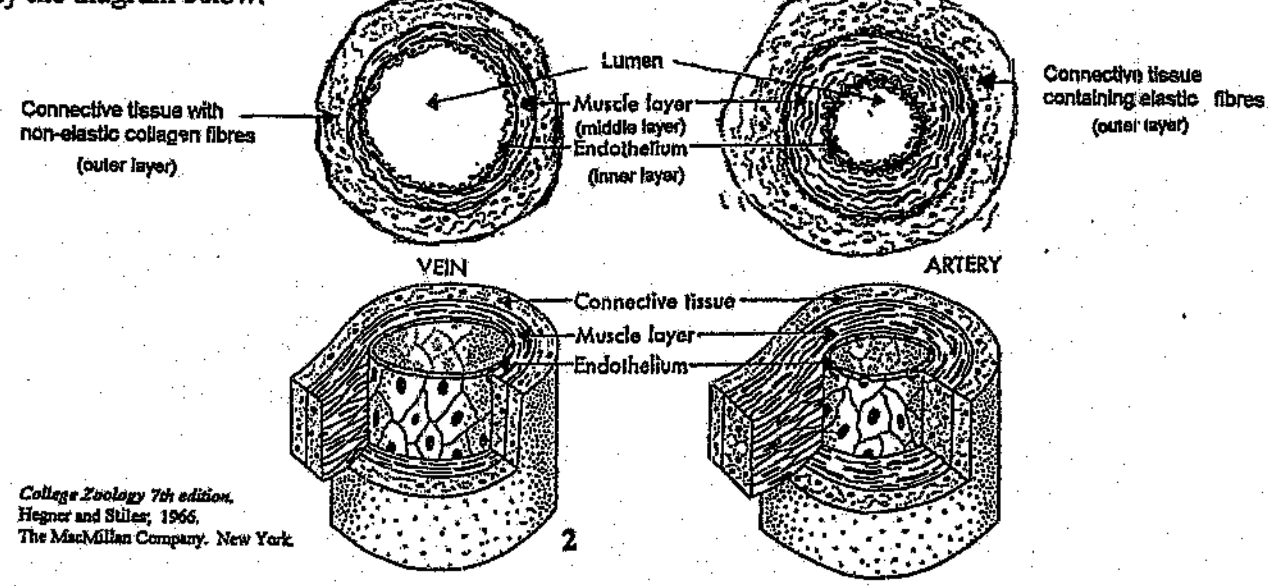
5. Study slide 7 of the blood supply to muscle fibres.
What do you notice about the blood vessels?

Why is it important that the muscle fibres have a good blood supply?

<u>Arteries and veins</u>

The walls of both arteries and veins are made up of three layers: an inner, a middle and an outer layer.

Study the diagram below:



Source: *College Zoology 7th edition.* Hegner and Stiles; 1966. The MacMillan Company. New York.

6. Study the diagram on the previous page and complete the following table of comparison between arteries and veins (please note that no actual measurements are required in the comparison - use words like larger, thicker, thinner, smaller, etc.).

	Arteries	Veins
1. Overall diameter	1.	1.
2. Size of lumen	2.	2.
3. Outer layer: a) thickness b) what the layer is made up of	a) b)	a) b)
4. Middle layer: a) thickness b) amount of muscle present	a) b)	a) b)
5. Inner layer: a) thickness b) what the layer is made up of	a) b)	a) b)

HOMEWORK

- **INVESTIGATION 6:** Harvey's experiment

1. Find a person who has prominent blood vessels on the inside of the forearm, and who is willing to cooperate. These prominent blood vessels beneath the skin are veins. The subject must clench the fist and rotate the hand inwards. Select a large vein usually to be found in the inner side of the forearm and choose a length which is unbranched. Work only on this section of the vein. A moderately tight bandage (or cloth tie) must be wrapped around the upper arm above the elbow. (Do not keep it tied for longer than 10 minutes). This should have the effect of increasing slightly the prominence of the vessels.

2. At the end of the vessel furthest from the elbow, apply a steady pressure in order to close its cavity.

3. Maintaining this pressure at the chosen point, stroke the vein firmly towards the elbow. (If the subject himself performs the operation he can use the opposite hand, applying stationary pressure with the little finger and stroking the vein with the thumb). Note the effect on the vein.

....

....

....

4. Now release the fixed pressure point and observe the effect.

....

....

....

5. Repeat (2) and (3) but <u>do not</u> release the pressure point after stroking the vein towards the elbow. With the pressure point maintained, stroke the vessel in the opposite direction i.e. from elbow side to pressure point. Observe what happens.

....

....

....

What do you deduce about the flow of blood in veins from this observation?

....

....

Suggest a possible mechanism in the vein responsible for the above observation.

....

....

....

In what direction does blood flow in veins?

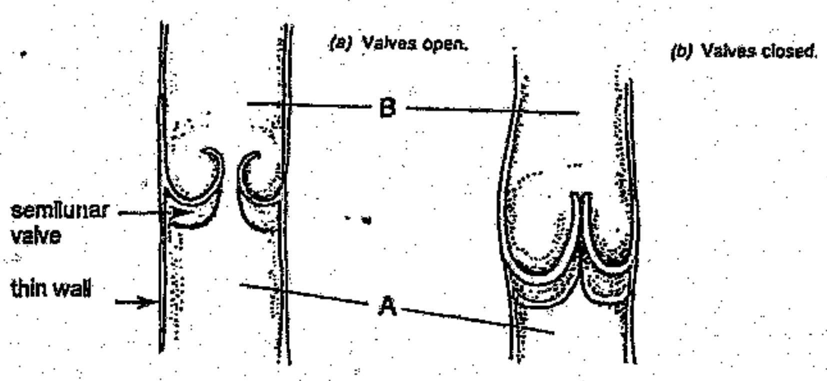
....

In what direction does blood flow in arteries?

....

One of the ways in which veins differ from arteries is that many veins have valves. Here and there along the channel of the vein, the inner lining has flap-like structures called semi-lunar or pocket valves (add this difference to the bottom of your table of comparison on page 3).

Study the diagram below:



Semilunar valves of a vein.

Source: *Biology for Today, Standard 8.* Austoker and Wessels; 1986. Juta & Co., Ltd. Johannesburg.

* In which direction would you expect blood to flow more easily, A > B or B > A?

....

Why?..

....

* Where would the heart be in relation to this diagram, below A or above B?

....

Lesson 5

The question Harvey never answered

Purpose of this lesson

The purpose of this lesson is:

- **to heighten pupils' understanding of the structure and functioning of blood capillaries through observation and deductive reasoning**
- **to enable pupils to discover the importance of elastic fibres in the wall of arteries in terms of the propagation of blood and blood pressure.**

Requirements

<u>**INVESTIGATION 7**</u>

- **one small (10-15 cm) goldfish per group**
- **one petri dish per group**
- **two microscope slides per group**
- **one strip of cotton wool (± 5 cm wide x 15 cm long) per group**
- **one stereo dissecting microscope per group**
- **Worksheet 5 (one per pupil)**

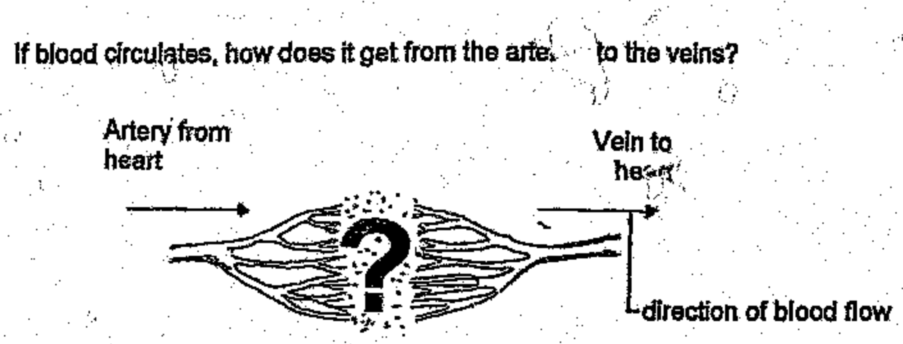
<u>**INVESTIGATION 8**</u>

- **one one-way plastic pump per group**
- **one 15 cm length of rubber tubing per group**
- **one "finger" of a rubber glove per group**
- **one glass dropper tube per group**
- **two pieces of string (10 cm) per group**
- **two 200 ml glass beakers per group**
- **Worksheet 5 (one per pupil)**

Suggested approach

- **It is suggested that pupils spend 30 minutes on INVESTIGATION 7 and that the second half of the lesson is used for INVESTIGATION 8.**
- **Encourage pupils to think carefully when answering the questions.**
- **Please emphasise that the goldfish will suffer no harm during the investigation as long as the cottonwool is kept wet.**

Worksheet 5 - The question Harvey did not answer



Harvey saw that blood left the heart at each beat and travelled along vessels termed "arteries". Harvey was not able to demonstrate any links between arteries and veins, but he predicted their existence. The first man to see the links was Marcello Malpighi (1628-1694) of Bologna in Italy. In the few years which separated the two men, great improvements had been made in the quality of lenses. With a powerful single lens Malpighi first saw blood <u>capillaries connecting arteries and veins</u> in the lung of a frog. Circulation (i.e. blood being pumped from the heart returns to it, to be pumped out again) thus became an established fact.

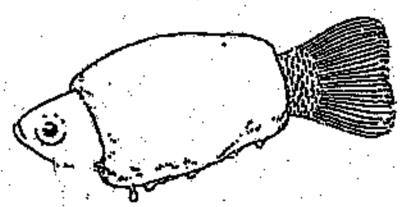
- **INVESTIGATION 7**

<u>Observing the flow of blood through the capillaries of a goldfish</u>

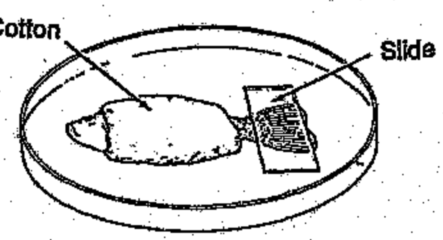
* Please note that a small cold-water goldfish will suffer no harm out of the water for 10-15 minutes, if it is wrapped in a wet cloth (or cottonwool), with its tail protruding. Never the less, work as quickly as you can, and only have the goldfish out of the water while you are observing it.

<u>Procedure</u>:

- Remove a small (10-15 cm) goldfish from the aquarium in your laboratory and wrap it (except for the mouth and tail) in dripping wet cotton. *(Note: Do not allow the cottonwool or cloth around the fish to dry out)* See diagram below:



- Place the fish in a petri dish as in the diagram below:



Source: *Laboratory outlines in Biology.* Abramoff and Thompson; 1991. WH Freeman & Co., New York.

If the fish moves too much, hold the tail fin still by pressing it down lightly with the microscope slide (the fish will come to no harm).

- Place the petri dish on the platform of a dissecting microscope and focus on the tail with the low-power objective of the microscope.

1. Describe what you see.

....

....

....

....

The smallest vessels are the capillaries. They are just wide enough to permit the passage of a single file of blood cells.

2. What is the advantage of having red blood cells pass through the capillaries in single file? (Refer back to the functions of red blood cells in your textbook)

....

....

....

....

Change to high power to examine the capillaries and blood cells more closely.

Blood enters the capillaries from small arteries called **arterioles**. Trace a capillary back to an arteriole.

3. Does the blood flow more rapidly in the arterioles or in the capillaries?

....

Follow a capillary in the direction in which the blood is flowing. It will join a slightly larger blood vessel called a **venule.**

4. Where does the blood flow faster - in the venules or in the capillaries?

....

5. Do red blood cells seem to be rigid or flexible structures?

....

* *At this stage, put your goldfish back in the aquarium.*

6. Where are exchanges between the surrounding tissues and the blood more likely to occur: in the arteries, veins or capillaries? Explain your answer.

....

....

....

....

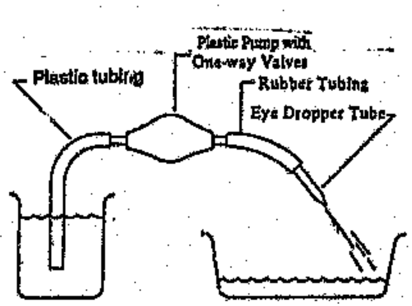
• INVESTIGATION 8

Demonstration of elasticity of arteries

Procedure:

- Attach rubber tubing to each end of a plastic pump with one-way valves. Attach a glass dropper tube to one end.

- Fill the system with water by holding the tube vertically while pumping the bulb as in the following diagram:



Source: *Biological Science. Molecules to Man. Teachers guide for BSCS.* Blue version; 1973. Haughton Mifflin Co. Boston.

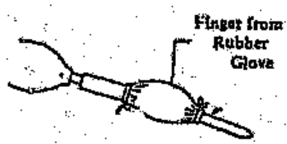
- Pump the bulb rapidly at regular intervals as if were a beating heart.

Describe how the water emerges from the dropper tube.

....

....

- Now attach an elastic rubber finger (from rubber glove) between the rubber tubing and glass tubing as in the diagram below:



- Begin the pumping action again.

What happens to the elastic rubber "finger"?

....

....

....

How does the water emerge from the glass dropper in comparison to the previous procedure without the elastic finger?

....

....

....

What do you think is the reason for arteries having elastic fibres and muscles in their walls?

....

....

....

Lesson 6

Consolidation/Blood pressure exercise

Purpose of this lesson

The purpose of this lesson is:

- **to check pupil answers to INVESTIGATIONS 6, 7 and 8**
- **to aid pupils in relating blood pressure fluctuations to the cardiac cycle, and**
- **to assist pupils to realise the role of blood pressure in the functioning of capillary networks**
- **to help pupils gain an understanding of the origin of lymph and the functioning of the lymphatic system.**

Requirements

- Worksheet 6 (one per pupil)

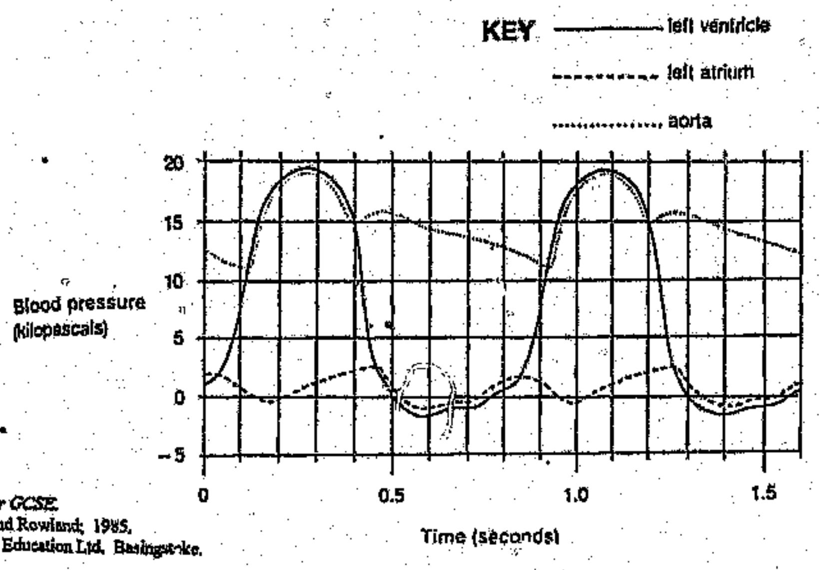
Suggested approach

- **The first 20 minutes of the lesson is to be used to check the answers to INVESTIGATIONS 6, 7 and 8.**
- **Pupils are then to begin answering the questions on Worksheet 6. Group discussions are to be encouraged, as pupils attempt to answer the questions.**
- **Pupils may have to complete the worksheet for homework.**

Worksheet 6 - Blood pressure exercise

Blood pressure exercise

Refer to the diagram below and answer the questions (1-3) that follow:



Source: *Biology for GCSE*, Alderson and Rowland; 1985, MacMillan Education Ltd, Basingstoke.

1. What is being plotted in this graph? *(look at the axes and the key to the three graphs for help)*

....

....

2. It can be seen from the graph that the blood pressure in the left ventricle increases and decreases rhythmically over time. Why do you think this may be so? Explain by referring to the flow of blood through the left ventricle, and relating it to the pressure pattern shown in the graph.

....

....

....

....

....

3. Is the semi-lunar valve at the entrance to the aorta open or closed during the period 0,2 sec - 0,3 sec? Explain.

....

....

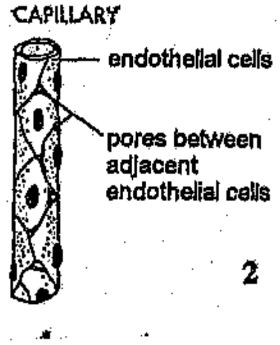
Doctors measure the blood pressure of a patient with a piece of equipment called a <u>sphygmomanometer</u>. A typical blood pressure reading is 120/80. Blood pressure is recorded and expressed as mm of mercury (mmHg), i.e. the height of a column of mercury that the pressure exerted by the blood can maintain. Two types of pressure are actually measured. In the example given above the 120 mmHg measures the <u>systolic pressure</u>, and the 80 mmHg measures the <u>diastolic pressure</u>.

4. Try to suggest what the <u>two</u> pressure readings actually measure? (Refer to Worksheet 2, page 5 for the meaning of systole etc.)

5. It has been found that blood pressure in arteries remains fairly constant, whilst it drops relatively constantly in veins and enters the heart at almost zero pressure. Try to suggest a reason for this. *(see INVESTIGATION 8)*

Capillaries are the narrowest of blood vessels. Their walls are made up of a thin single layer of endothelial cells *(see INVESTIGATION 7)*. There are tiny pores between adjacent endothelial cells. Every cell of the body is close to blood capillaries. Every cell of the body is surrounded by a colourless fluid called **tissue fluid**.

CAPILLARY



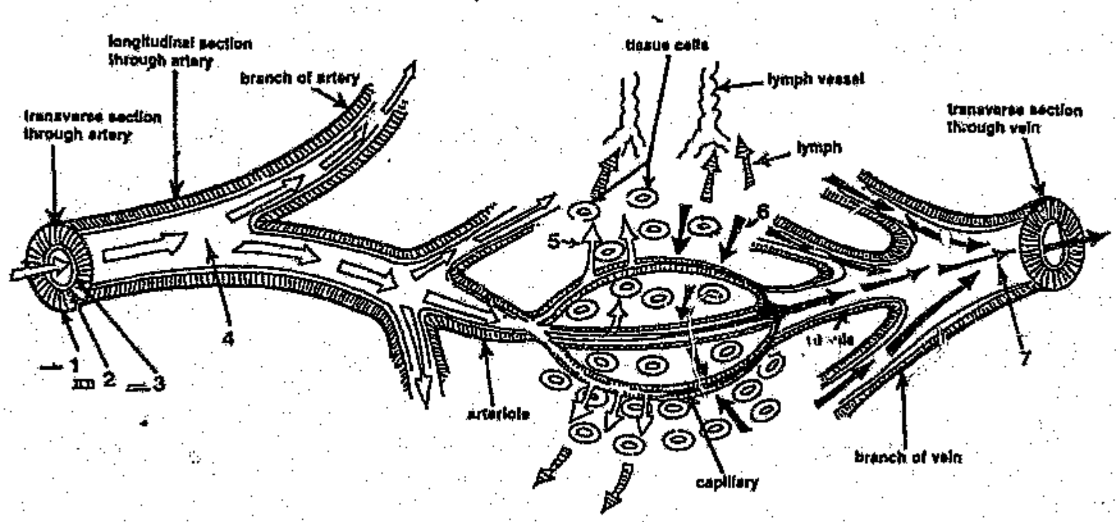
6. Where do you think the tissue fluid originates from?

....

....

....

Study the diagram below:



Scheme of branching of artery to form arterioles and capillaries, and the venule and veins carrying blood away from the capillary network.

Source: *Biology for Today. Standard 8,* Austoker and Wessels; 1986. Juta & Co., Ltd. Johannesburg.

As long ago as 1622 an Italian, Gasparo Aselli, discovered a series of tubes lying alongside blood vessels. Aselli did not understand their function but we now know them to be part of a series of vessels (called **lymph vessels**) that contain an almost colourless fluid known as **lymph.** Lymph vessels contain valves similar to those of veins, so that lymph can flow only in one direction. Small lymph vessels unite to form a main lymph vessel (the **thoracic duct**) which drains in the **left subclavian vein** (blood vessel in the left shoulder returning blood to the heart). A number of **nodes (glands)** are found along the lymph vessels, particularly in the neck, arm pits and groin. They produce cells called **lymphocytes** that engulf and destroy bacteria.

7. Explain how lymph fluid originates. *(Consult your textbook for help)*

....

....

....

....

8. What is the function of the lymphatic system? *(Consult your textbook for help)*

9. Tabulate five differences between the blood in an artery *(see label <u>4</u> in diagram on page 3)* and that in a vein *(see label <u>7</u> in the diagram on page 3)*.

Blood in artery	***Blood in vein***

The lymphatic system has <u>no</u> "pumping mechanism" that "pumps" the lymph in the lymphatic vessels.

How do you think the lymph is then able to move up lymph vessels in one's leg? Consider the bank teller that stands behind a counter all day and arrives home with swollen and puffy ankles and feet **(oedema)**. If the teller now goes for a run, the swelling goes down. How would you explain this phenomenon? *(Refer to your textbook if you need help)*

....

What other way/s can you think of to reduce the puffiness of the feet? Explain.

....

....

....

....

Elephantiasis (filariasis) is a disease characterised by massive swelling of the arms and legs.

Source: *College Zoology 7th edition.* Hegner and Stiles; 1966. The MacMillan Co. New York.

Most elephantiasis is due to the presence of filaria worms in the lymphatic system. These parasitic round worms actually live in the lymph vessels. The adult female worm may reach a length of 50 cm and is often thicker in diameter than certain lymph vessels. What do you think might be the reason for the severe swelling in the limbs of a human infected with filaria worms?

....

....

....

....

What other way/s can you think of to reduce the puffiness of the feet? Explain.

....

....

....

....

Elephantiasis (filariasis) is a disease characterised by massive swelling of the arms and legs.

Source: *College Zoology 7th edition.* Hegner and Stiles, 1966. The MacMillan Co. New York.

Most elephantiasis is due to the presence of filaria worms in the lymphatic system. These parasitic round worms actually live in the lymph vessels. The adult female worm may reach a length of 50 cm and is often thicker in diameter than certain lymph vessels. What do you think might be the reason for the severe swelling in the limbs of a human infected with filaria worms?

....

....

....

Lesson 7

Systemic circulation and final consolidation

Purpose of this lesson

The purpose of this lesson is:

- to enable pupils to get an understanding of systemic circulation and thus to grasp the pathways of blood to and from various body organs
- to enable pupils to get an understanding of the role of the hepatic portal system in terms of the absorption of nutrients and the role of the liver
- to enable pupils to deduce the role of the lymphatic system in the absorption of fats
- to check the answers of Worksheets 6 and 7.

Requirements

- Worksheet 7 (one per pupil)

Suggested approach

- The first 30 minutes of the lesson is to be used for pupils to answer the questions on Worksheet 7. Group discussion should be encouraged.
- It is suggested that the teacher alert the pupils to the relationship between the two diagrams on page 1 of Worksheet 7. Please explain to the pupils that the arteries in the upper diagram form capillaries (in various organs not shown in the diagram) which give rise to the veins seen in the bottom diagram. The pupils must be aware of the connection between the arteries and veins of the two diagrams.
- The last 30 minutes are to be used to check the answers of Worksheet 6 as well as those of Worksheet 7.
- Remind pupils that they must hand in their assignments (coronary thrombosis) in the next lesson.
- Pupils are to be told of a test on the circulatory system, one week from today.

Worksheet 7 - Systemic circulation

<u>The major arteries and veins of the body.</u>

Study the two diagrams below and answer the following questions.

The main arteries in the human body.

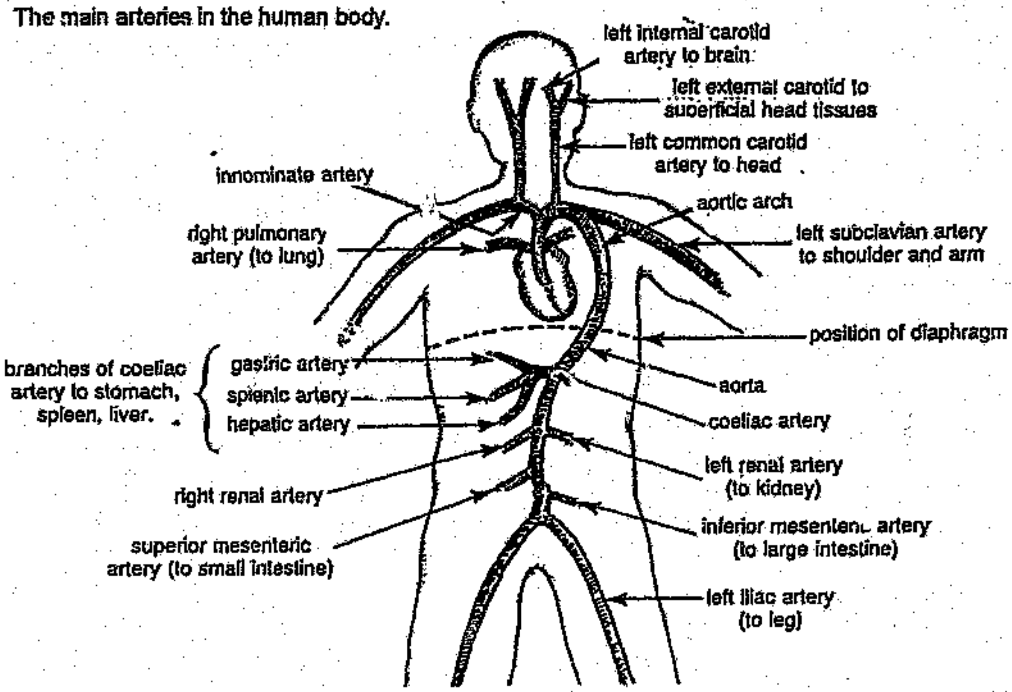
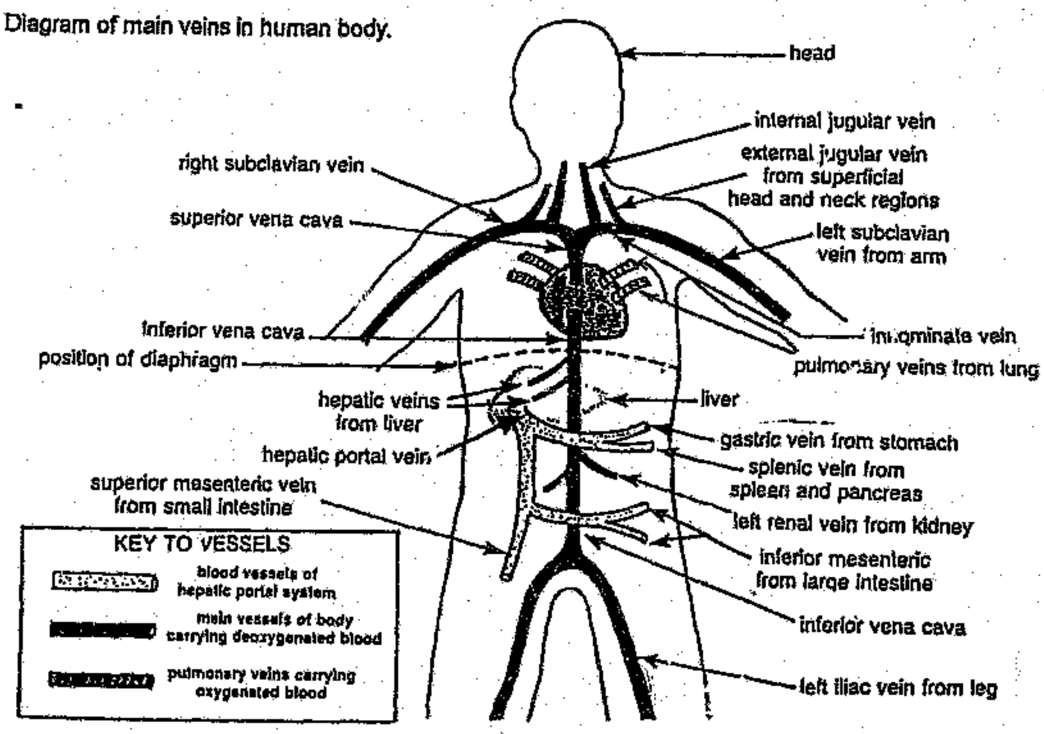


Diagram of main veins in human body.



Source: *Biology for Today. Standard 8.* Austoker and Wessels; 1986. Juta & Co., Ltd. Johannesburg.

1. List the names of the blood vessels in correct sequence through which a red blood cell starting in the gastric artery will have to travel to get to the left subclavian vein.

2. Name the <u>common</u> blood vessel into which blood <u>from</u> the stomach, small and large intestine drains after leaving these organs?

3. Which is the first organ reached by blood travelling from the stomach, small and large intestine?

The **hepatic portal vein** is the only blood vessel which commences <u>and</u> ends in capillaries.

4. Analysis of the chemical composition of blood in the hepatic portal vein during a 24 hour period shows varying levels of sugar, amino acids and other nutrients in the blood. Look carefully at where this blood comes from and suggest a reason for the changes in the levels of these nutrients.

5. Analysis of the chemical composition of blood in the <u>hepatic veins</u> indicates <u>constant levels</u> of sugar, amino acids and fatty acids in the blood throughout a 24 hour period. What does this suggest about the functions of the liver?

....

....

....

6. The blood in the hepatic portal vein contains <u>no</u> fatty acids and glycerol (from the digestion of fats). The hepatic artery <u>does</u>. This suggests that fats are <u>not absorbed into the blood</u> from the intestines, but rather into some other means of transport and only enters the blood later. Explain how you think the absorption and transportation of fats occur. *(Consult your textbook for help)*

....

....

....

....

APPENDIX B

References used in developing the inquiry teaching package

ABRAMOFF, L. and THOMPSON, K. (1991). **Laboratory outlines in Biology**. New York:W.H. Freeman and Company.

ALDERSON, P. and ROWLAND, T. (1985). **Biology for GCSE.** Basingstoke: MacMillan Education Limited.

AUSTOKER, J. and WESSELS, H.J. (1986). **Biology for Today. Standard Eight.** Johannesburg: Juta and Company Limited.

Biological Science. Molecules to Man. Teacher's Guide for BSCS (1973). Boston: Haughton Miflin Company.

HEGNER, A. and STILES, E. (1966). **College Zoology 7th Edition**. New York: The MacMillan Company.

MORHOLT, E., BRANDWEIN, P.F. and JOSEPH, A. (1966). **A sourcebook for the Biological Sciences.** New York: Harcourt Brace Jovanovich.

ROBERTS, M.B.V. and KING, L. (1987). **Biology a functional approach - Students Manual.** Surrey: Thomas Nelson and Sons Limited.

Evaluation:

Lesson 1

1. Please list any problems you experienced with this lesson regarding:
   - Length of lesson: Started with an introduction 6th period Mon 24/10 (30' period) Actual experimental work during periods 3 & 4 on Tuesday.
   - Practical problems in doing investigations: Did not ensure that the mouth of the eyedropper was wide enough to accomodate Daphnia.
   - Content taught: As per instructions, no formal lesson was provided. Pupils were to establish a relationship between heart rate of Daphnia and temperature.
   - Any other problems: Pupils counted leg twitches instead of heart rate. High teacher involvement necessary to identify heart, despite pupils having drawing of Daphnia. Other problem is that many pupils did not read the instructions prior to the lesson.
2. Which parts of the lesson worked well?
   - Your opinion (e.g. parts that would improve pupil understanding): Lesson was enjoyed for its novelty aspect. Could possibly ask pupils to predict outcome on basis of personal experience.
   - Pupils' response (e.g. parts that pupils enjoyed, found interesting/fun etc.): Pupils had difficulty with the graph. Had to be provided with appropriate scales for the axes. Results were not very accurate. Post experimental "ideal" data was provided for cmpsn.
3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?
   This varied from group to group. Consicetious groups had sufficient time. Other groups did not. One group killed their water fleas through bad handling.
4. Write down any errors (content of otherwise) you may have found in the pupil worksheets?
   No errors of content. Perhaps in addition to the data table, the pupils could have been provided with a photocopy of the graph paper with the axes drawn to the correct scale.
5. Please write down any suggestions you may have for improving this lesson?
   A point of concern regarding blood manufacture by liver. In the section of work dealing with connective tissue, we discussed the removal of old blood cells by liver and spleen, at a rate of 2.6 million per second. Although this is a minute fraction of the total blood cells available, I don't think the large numbers mentioned in the text book have a quantitative meaning for the pupils. P.T.O

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

Maybe should suggest that Aristotle was not totally wrong. Blood cells are replaced but the rate of 2,6 million cells a second although sounding large (As it is intended to impress during the discussion on connective tissue) is in fact a very small percentage of the total (0.00001%)
Unless carefully noted by the pupils, the contradiction in what was previously taught and the current concept that the heart functions only as a pump could produce a conceptual dissonance.

Evaluation:

Lesson 2

1. Please list any problems you experienced with this lesson regarding:

- Length of lesson: 60' was adequate for the external examination and dissection of the heart.
- Practical problems in doing investigations: Difficulties were experienced in fitting rubber tubes to the blood vessels without getting leaking and deciding where the blood emerged.
- Content taught: The pupils enjoyed the "hands on" dissection approach. Had difficulties seeing the tricuspid and mitral valves.
- Any other problems: Again a lot of teacher supervision is necessary to answer all the questions and queries. Difficult to ensure that pupils carry out dissecting instructions faithfully.

2. Which parts of the lesson worked well?

- Your opinion (e.g. parts that would improve pupil understanding): Get pupils to draw diagram of the heart they are dissecting
- Pupils response (e.g. parts that pupils enjoyed, found interesting/fun etc.): Some pupils were squeamish. Some relished the thought of dissecting. Generally enjoyed the practical, again for its novelty aspects.

3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?

There should have been. Pupils were more concerned with the actual cutting up of the heart than with filling in the answers.

4. Write down any errors (content of otherwise) you may have found in the pupil worksheets?

Question 8 relating to the relative sizes of the chambers of the heart. I could not find any information on this, but suspect that the ventrecles of the same size although the left hand side is more muscular.

5. Please write down any suggestions you may have for improving this lesson?

Pupils answers to the questions were for the most part very superficial in therms of the answers expected. Perhaps some guidlelines of pointers to make the questions more specific.

The box heart diagram is a very good idea.

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

Evaluation:

Lesson 3

1. Please list any problems you experienced with this lesson regarding:

- Length of lesso. 60 ' (Double period.) . Theoretically this should hav been sufficient time, for some inexplicable reason was not. Some of the practical spilled over to next lesson
- Practical problems in doing investigations.
  Stopping the boys listening to the girl's hearts. Groups were not classified into boys only and girls only. Opportunity for Horseplay
- Content taught.
  A considerable amount of explanation was required for time lag between heart & pulse and calculation of blood speed.
- Any other problems.
  No other problems.

2. Which parts of the lesson worked well?

- Your opinion (e.g. parts that would improve pupil understanding).
  Listening to heart beats and measuring pulse is beneficial.
- Pupils response (e.g. parts that pupils enjoyed, found interesting/fun etc.)
  Generally the lesson was enjoyed.

3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?
   See #1. Pupils had fun with stethoscopes and a certain amount of unofficial use was made of the stethoscopes.
   Checking answers and marking needed extra time.

4. Write down any errors (content of otherwise) you may have found in the pupil worksheets?
   Pupils generally had difficulty with Question 3 and calculation of blood speed. Concept of speed being distance/time not totally appreciated.

5. Please write down any suggestions you may have for improving this lesson?
   No suggestions.

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

Evaluation:

Lesson 4

1. Please list any problems you experienced with this lesson regarding:
   - Length of lesson: 30' (marking previous work) + 60' to do and correct homework on direction of blood flow.
   - Practical problems in doing investigations: Only problems associated with handling many groups of talkative pupils.
   - Content taught: No problems.
   - Any other problems: Getting pupils to appreciate that a practical lesson also involves observing and recording results.

2. Which parts of the lesson worked well?
   - Your opinion (e.g. parts that would improve pupil understanding): Correlation between exercise and heart rate is very definitely established.
   - Pupils' response (e.g. parts that pupils enjoyed, found interesting/fun etc.): Generally enjoyed the practical aspects.

3. Was there sufficient time for pupils to complete the worksheets (excluding homework)? Yes. Homework was enjoyed. i.e. pasting names on diagram instead of simply writing labels out.

4. Write down any errors (content of otherwise) you may have found in the pupil worksheets? Explanations involving increased demand on heart for oxygen & nutrients when working harder were not concise. Idea of blood-flow being supplier of nutrients not always grasped.

5. Please write down any suggestions you may have for improving this lesson? Explanation of use of stethoscope and how it functions prior to letting pupils get their hands on the instrument may have been beneficial.

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

INVESTIGATION 5

Biostrip viewing practical: No problems. Also used time to check up on all work done to date.

Pupils found difficulty in answering the questions to the same depth as provided by the model answers. In most cases, their anwers had to be supplemented to provide them with fuller and more informative answers.

INVESTIGATION 6

Harvey's experiment.

Don't know the extent of penetration the significance of Harvey's work had on the pupils. Hard to get them to appreciate with the benefit of hindsight how remarkable Harvey's conclusions were. I think that by this stage of their careers, most of the pupils know that blood flows towards the heart in the veins. Harvey's experiments instead of being seen as pioneering work, is regarded with a 'so-what' attitude.

Evaluation:

Lesson 5

1. Please list any problems you experienced with this lesson regarding:
   - Length of lesson: 60' for investigations 7&8
   - Practical problems in doing investigations: Bioviewer strip results also had to be concluded.
   - Content taught: No problems except for exercising care with handling of goldfish and inserting rubber tubes into pumps.
   - Any other problems: Having to personally supervise what the pupils are in fact seeing. A lot of demands made on the teacher to see if what is being viewd is what is supposed to be seen.
2. Which parts of the lesson worked well?
   - Your opinion (e.g. parts that would improve pupil understanding): Actually seeing the blood traveling through the blood vessels.
   - Pupils' response (e.g. parts that pupils enjoyed, found interesting/fun etc.): The expansion of the tube walls to suppress pumping action and ensure smoother flow was appreciated.
3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?
   Yes. By this time in the project, a lot of unseen work had to be controlled and correct answers supplied.
4. Write down any errors (content or otherwise) you may have found in the pupil worksheets?
   Not particularly incorrect anwers but vague answers as if the pupils have difficulty in expressing themselves in describing what they see. Easier to provide oral answers.
5. Please write down any suggestions you may have for improving this lesson?
   Pump experiment is useful in demonstrating smoothing of pulses, but in terms of the time taken to demonstrate it, it might be more useful and quicker to have two sets of apparatus set up, one with stiff piping and the other with elastic tubing ratheer than have the pupils tying on their own fingers

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

Evaluation:

Lesson 6

1. Please list any problems you experienced with this lesson regarding:

- Length of lesson: 60' Time was adequate for the lesson.
- Practical problems in doing investigations: Pupils found it difficult to relate the answers to the questions to the information supplied by the graph.
- Content taught: This work is perhaps a little abstract for most of the pupils. Correlating valve opening & closing with changes in slope of the graph had most of them beat.
- Any other problems: The concept of an alternative system to the circulatory system is a difficult one to appreciate (it would appear). Perhaps a diagram of the total lymph system prior to nomenclature would have helped.

2. Which parts of this lesson worked well?

- Your opinion (e.g. parts that would improve pupil understanding): The diagram of the capillary and the Scheme of branching artery etc taken from Austoker & Wessels.
- Pupils response (e.g. parts that pupils enjoyed/found interesting/fun etc.): Pupils didn't see this lesson as being all that radically different from the traditional method of teaching.

3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?

Yes. Again some time was spent in ensuring all the material from previous lessons was up to date and correct.

4. Write down any errors (content of otherwise) you may have found in the pupil worksheets?

Pupils experience difficulty in being able to determine from the graph when valves are opening and closing. Don't appreciate that pressure falls when the valve opens, and that closure of the valve hearlds a rise in pressure in chamber or aorta

5. Please write down any suggestions you may have for improving this lesson?

A video or working model which shows pressure increasing as heart contracts with closed veins.

Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

Evaluation:

Lesson 7

1. Please list any problems you experienced with this lesson regarding:

- Length of lesson: 40'. Due to school writing english essay, some time was lost. Lesson had to be rushed. Answers to questions 4 & 6 were not given in full.
- Practical problems in doing investigations: None
- Content taught: A lot of terminology. Difficult to asses how much information is acquired by the pupils during the lesson.
- Any other problems: None.

2. Which parts of the lesson worked well?

- Your opinion (e.g. parts that would improve pupil understanding): Question & answer approach. Especially the following the sequence of vessels through a red blood cell has to pass.
- Pupils response (e.g. parts that pupils enjoyed, found interesting/fun etc.): Not a particularly exciting lesson for the pupils. Last lesson so lots of outstanding details needed to be provided.

3. Was there sufficient time for pupils to complete the worksheets (excluding homework)?

Normally would have been.

4. Write down any errors (content or otherwise) you may have found in the pupil worksheets?

Pupils answers to questions 4 & 6 were sparse.

5. Please write down any suggestions you may have for improving this lesson?

Maybe the lesson could have been in the same style as the momework exercise of lesson 3. The pupils could have pasted names of blood vessels onto a diagram instead of having all the information given them.

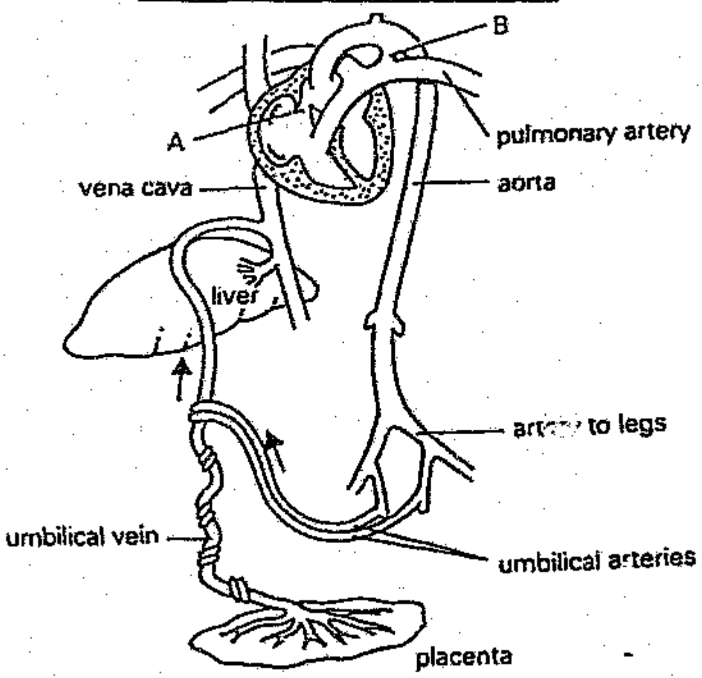
Please use reverse side of this sheet if I have left insufficient space. Add any other comments you wish to make.

TEST - Circulatory system *Time: 40 minutes*

Instruction: Answer all questions on the double folio paper provided.

1. Although you never studied the blood system of a human foetus, your knowledge of the mammalian circulatory system will enable you to work out the answers to this question. A human foetus (developing inside its mother) receives its food and oxygen from its mother's blood at the placenta (in the uterus). The lungs do not function until birth. The structure of the foetal blood system is slightly different from an adult's blood system, to help in its functions. The diagram below shows the structure of the foetal blood system. From the diagram you can see that there is a hole in the wall between the atria of the heart (*labelled A*), and a vessel (*labelled B*) connecting the pulmonary artery and the aorta. The hole A and the connection B close just after the birth of the baby.

The blood system of a human foetus.



a) Explain why A and B are important to the foetus. (4)

b) Suggest what would happen if A and B remained open after birth. (4)

c) List the names of the structures and vessels of the most direct route by which oxygen could be carried in the blood from the placenta to the legs of a foetus. (6)

[14]

2. a) Imagine yourself to be a red blood cell in the main vein of one of your legs. List the vessels, heart chambers, and other structures you would pass through, in the correct sequence, before you arrived once more in the same leg (13)

b) How many times did the red cell pass through

(i) the lungs, and

(ii) the heart? (2)

[15]

3. a) Why is there a difference in thickness between the walls of the atria and ventricles?(2)

b) What do you think might account for the difference in wall thickness between the left and right ventricles? (2)

[4]

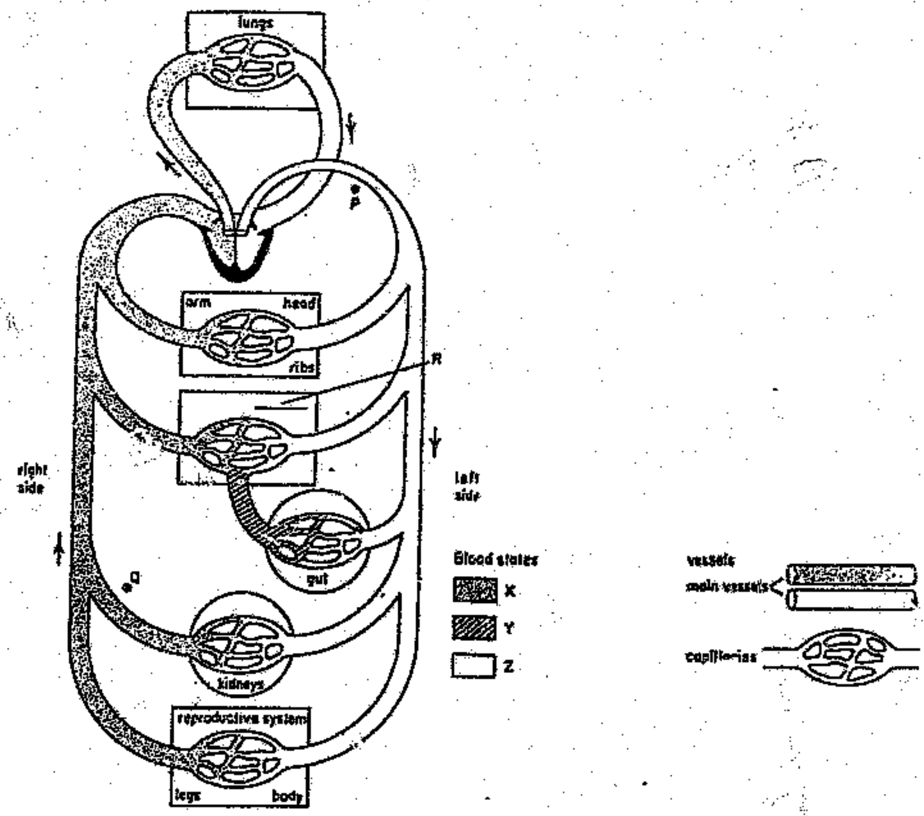
4. The blood system has been likened to a bus route. In this comparison, each of the items listed on the left below is equivalent to one of those on the right. Write them down in the correct pairs, and give a reason for your choice.

Circulation	Bus route
heart	roads
red blood cells	engine of the bus
oxygen	buses
vessels	passenger

[8]

5. Explain the statement: "Our closed blood system is leaky". [4]

6. Study the diagram below of a circulatory system and answer the questions that follow.



a) Why is this called a double circulation? (3)

b) Find three differences between the blood circulation in the above diagram and the real blood circulation in a mammal. (3)

c) **To answer this question, you need to tear off and use the attached diagram of the heart at the back of the question paper.**

Early medical thinkers like Galen (about AD 129-200) thought that the heart sent the blood out to the body from the left ventricle. Then the right ventricle sent vapours out along the pulmonary artery and the blood crossed into the left ventricle through invisible pores. Label the attached diagram to show what Galen thought (use arrows). Mark with a tick ideas which biologists believe are correct. Mark with a cross ideas that we think are wrong. *Insert diagram page into your test script.* (4)

[10]

7. Discuss the differences between arteries and veins in regard to:

a) the relative amounts of oxygen and carbon dioxide in the systemic circulation of humans; (2)

b) the relative amounts of oxygen and carbon dioxide in the pulmonary circulation of humans; (2)

c) the direction of blood flow; (2)

d) the pressure of the blood; (2)

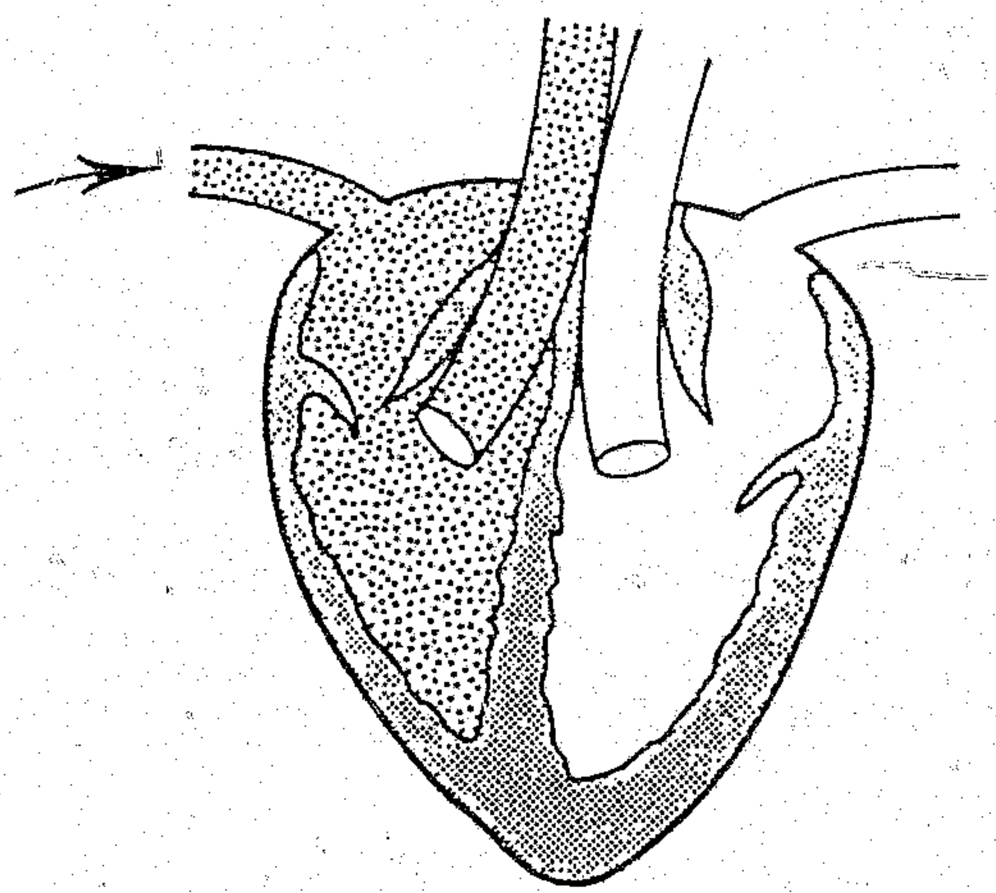
e) the thickness of the walls. (2)

[10]

TOTAL = [65]

Insert this diagram page into your test script.

QUESTION 6C:



Circulatory system - Test of Understanding

MEMORANDUM

1a) Both A and B result in most of the oxygenated blood passing directly from the placenta to the main body circulation, bypassing the lungs which have no function in the foetus. (4)

b) Blood would continue to bypass the lungs and would not therefore be fully oxygenated. The tissues of the body would not respire efficiently/not be getting enough O2, causing weakness etc. (4)

c) Umbilical vein --> vena cava --> right atrium --> left atrium --> left ventricle --> aorta --> arteries to legs. (6)

2a) Femoral vein --> inferior vena cava --> right atrium --> tricuspid valve --> right ventricle --> pulmonary artery -> lungs --> pulmonary veins --> left atrium --> bicuspid valve --> left ventricle --> aorta --> iliac artery. (13)

b) (i) once
(ii) twice (2)

3a) Walls of atria don't need to contract as blood only has to be forced into the ventricles directly below them.
Walls of ventricles need to be thicker with more muscle fibre for strong contractions to force blood under pressure over longer distance (to the lungs and tissues of body). (2)

b) The right ventricle has to pump blood to the lungs which are close to the heart.
The left ventricle has to pump blood to all tissues of the body. Left ventricle . . needs stronger contractions . . has thicker muscular walls. (3)

4) Heart - engine of the bus - in both cases work is done to bring about movement.
red blood cells - buses - buses transport people as red blood cells transport oxygen.
oxygen - passenger - both are transported to destination.
vessels - roads - route along which is travelled. (8)

5)
- Capillaries are thin walled vessels/ comprising a single endothelial layer.
- In the capillaries blood plasma leaks out through tiny pores (4)

6a) Two paths of blood flow:
heart - lungs - heart
heart - body - heart. (3)

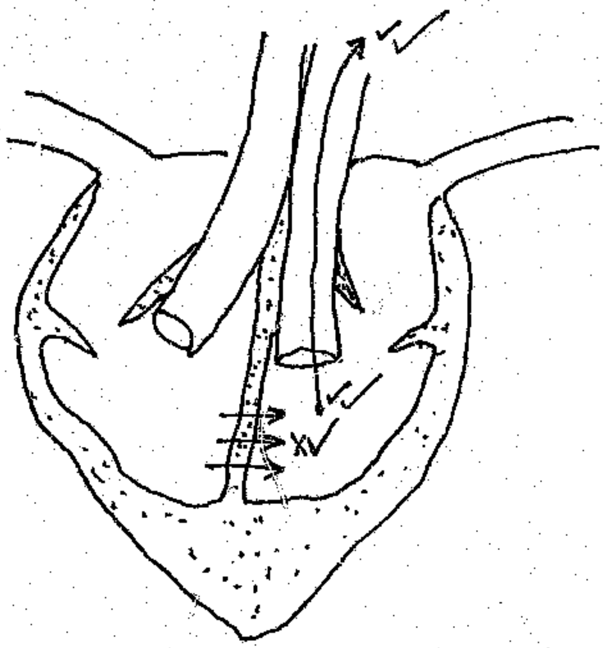
OR

Heart acts as if it is two separate pumps:
Blood is pumped from heart (right side) to lungs and back to heart.
Blood is pumped from heart (left side) to all body tissues and back.
(3)

b) - blood does not travel down one side of the body and up the other
- two venae cavae, only one shown on diagram
- 2 chambered heart incorrect, should have four chambers
- valves in veins - none in diagram
- valves in heart - none in diagram
- lungs not shown as two organs
- lungs are above the heart
- capillaries in the arms, head and ribs should be separate
- capillaries in the legs and reproductive system should be separate
- aorta and pulmonary artery should cross over.

Any (3)

c)



(3)

7. Arteries	Veins
a) ↑ O_2 ↓ CO_2	↑ CO_2 ↓ O_2
b) ↓ O_2 ↑ CO_2	↓ CO_2 ↑ O_2
c) Away form heart	towards heart
d) higher	lower
e) thicker	thinner

(10)

TOTAL [64]

APPENDIX F
Attitude Towards School Biology Test

STD._____ BIOLOGY OPTION:_____

YOUR NAME IS NOT REQUIRED.

Attitude toward Biology in School Assessment.

Please use this scale to answer the following questions:

SA - Strongly agree
A - Agree
N - Neither agree nor disagree
D - Disagree
SD - Strongly disagree

(Circle **ONE** choice.)

(1) SA A N D SD Biology is fun.

(2) SA A N D SD I do not like biology and it bothers me to have to study it.

(3) SA A N D SD During biology class, I usually am interested.

(4) SA A N D SD I would like to learn more about biology.

(5) SA A N D SD If I knew I would never go to biology class again, I would feel sad.

(6) SA A N D SD Biology is interesting to me and I enjoy it.

(7) SA A N D SD Biology makes me feel uncomfortable, restless, irritable, and impatient.

(8) SA A N D SD Biology is fascinating and fun.

(9) SA A N D SD The feeling I have towards biology is a good feeling.

(10) SA A N D SD When I hear the word biology, I have a feeling of dislike.

(11) SA A N D SD Biology is a topic I enjoy studying.

(12) SA A N D SD I feel at ease with biology and I like it very much.

(13) SA A N D SD I feel a definite positive reaction to biology.

(14) SA A N D SD Biology is boring.