AN EXPERIMENTAL STUDY IN THE PROCESS OF ABSTRACTION FROM
VERBAL AND AUDIO VISUAL TO DIAGRAMMATIC
FORMS IN THE TEACHING OF GENERAL SCIENCE.

by
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M. B. BEDRI.
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CHAPTER I.

INTRODUCTION.

(i) Audio visual instruction and the process of abstraction

The heavy hand of verbalism has been the greatest enemy of audio visual instruction for many centuries. The movement started by Comenius (1592-1670), Rousseau (1712-1778), Pestalozzi (1746-1827), Herbert (1776-1841), and Froebel (1782-1852), against the tradition of oververbalization is still going on. The development of the psychology of learning has loosened the grip of verbalism by calling attention to the fact that the process of abstraction and concept building proceeds from the concrete to the abstract through the antithetical processes of differentiation and integration.

Hence, to pave the way for proper abstraction, direct and contrived audio visual aids have become an absolute necessity. The printed page, the symbolic representation of word symbols, which was the most important item in formal child education, has lost much of its significance as the central focus of effective learning.

Recent research work in the process of abstraction and concept formation has verified that the verbal use of a concept is not a proof that it is well abstracted. L.C. Pressy¹ proved that American secondary school children were ignorant of many concepts used freely in their social science textbooks, in spite of the fact that they succeeded in

¹ L.C. Pressy, "Study in the learning of the Fundamental Special Vocabulary of History from the Fourth through the Twelfth Grades", A study abridged by Gates et al, Educational Psychology, p.186.
using these concepts correctly in their oral conversations. These results indicated that the child does not get meaning from the concepts he reads or hears in a lecture, but he gives meaning to them by relating them to his past concrete experiences.

On the other hand, a variety of experimental work carried out by psychologists like Smoke\(^1\) and Hull\(^2\), have shown that subjects might fail to give satisfactory verbal definition of a concept though they were entirely capable of using it, which reduces the importance of the spoken or written word as the only channel of instruction, and proves the importance of vision and kinaesthetic learning in abstraction and concept forming.

The fact that almost any modern book about audio visual education starts with a chapter about the process of abstraction and concept building is a strong indication that this psychological principle has probably given audio visual instruction its greatest justification.


(ii) **Audio visual instruction and science teaching:**

Audio visual materials lend themselves quite easily to the teaching of general sciences, because science depends mostly on observation and sense perception. It can be very abstract when taught through verbal methods only, and it becomes very exciting, meaningful and interesting once rendered concrete by audio visual aids. Of all the school subjects, the teaching of general science is probably the most affected by recent developments in concrete and semi-concrete audio visual aids. Concrete audio visual aids either take the students of science to the outside world, to get first hand impressions from the breath-taking heat of a glass furnace or the sharp pungent odours of a tanning room, or bring the outside world into the classroom in the form of specimens, exhibits and school museums.

When the real thing is too far to be visited, too messy or complex to study as it exists, too ancient, takes too much time to study, too big to be brought into the classroom, too small, too fast or too slow to be seen or followed by the unaided eye, the role of contrived and semi-concrete audio visual methods and materials come into the scene.

A model can place the earth, the sun and the moon on the science masters' table or enlarge the atom to the extent that the electrons and

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1 Some of the ideas in this section are condensed from:


protons can be seen from the back of the classroom. By the aid of
the microscopic or telescopic lens, science learners can see a one-
celled animal magnified by projection to the size of giant, or bring
into focus huge galaxies which are millions of light years away from
the earth. The diorama, the still picture, or the film strip can
transcend time dimension to unveil the shape of extinct and prehistoric
animals in their natural habitat.

Students of science may learn very little use by studying
an engine of an actual motor-car or the cross-section of a real bull's
eye, but a working mock-up of the internal combustion engine, or the
cutaway model of the human eye can be of greater value than the real
object. Taking a class on a field trip to a refinery will show them
nothing other than pipes and huge tanks, but by the help of animation,
the child can see exactly what process and reaction takes place in each
tank or boiler. Through animated diagramatic drawings, the motion
picture can even show very highly abstract concepts such as sound waves,
the exchange of carbon dioxide and oxygen in blood circulation, or the
flow of electrons through a wire.

To follow the life cycle of certain animals and plants, or to
study the making of paper from trees would take much time and effort;
a set of carefully prepared still pictures, graphic materials or a
film can give an effective edited version of reality. Hence, complete
processes which at normal times extend over periods of months, and
which take place at different localities separated by hundreds of miles,
can be concretely presented in a few minutes.
Through the techniques of high-speed and time-lapse photography, the cinema can distort or condense the time factor to slow down or speed up processes in nature and industry which are too fast or too slow to be detected by the human eye. Thus students of science can actually see insects carrying pollen grains from anthers to the stigma of a flower, projectiles coming out of guns, or human vocal chords producing sound. On the other hand experiments of botany that need days and weeks to perform are watched in a few seconds. Children are able to see opening buds, unfolding leaves, and plants growing quickly towards the sunlight.

In countries in which science teaching has increased considerably audio visual instruction has probably given the science education its greatest impetus. This has been verified by Edgar Martin\(^1\) who carried out a study to evaluate the teaching of general biology in the public high schools of the United States of America. 55.3 of the schools offering general biology responded to the question "What changes or innovations have been made in the last five years, which you feel have contributed significantly to the education of the youth in your school?" The increased use of audio visual aids and biological equipment ranked first. It was reported by 261 schools, (61.4% of the schools offering general biology), which is more than twice the number of schools that reported the second most significant innovation.

It may be argued in this connection that this impetus which audio visual instruction has given to science teaching is probably the reason

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\(^1\) W. Edgar Martin, ed. *The Teaching of General Biology in the Public High Schools of the United States*, p.42
for the difficulty that one faces when one tries to differentiate between the methods of teaching general science and the audio visual materials for improving these methods. While Richardson and Cahoon give the demonstration and the field trip as methods of teaching science, Edgar Dale and Hass and Packer present the laboratory method itself as an audio visual material; the former gives the demonstration a separate chapter among the other audio visual aids. Many general science textbooks consider the motion picture projector, the filmstrip, slide, and micro-projectors as logical parts of the laboratory equipment, while some visual aids books classify the microscope and the microscopic slides as visual aids.

Evidently any attempt to draw a line between the methods of teaching general science proper, and the audio visual materials for improving these methods is a misunderstanding of the role of audio visual methods and materials as an aid to learning and not an end in themselves. Yet the inclusion of general science teaching methods like the laboratory and the demonstration methods in audio visual instructions textbooks has definitely vitalized the teaching of general science. Principles for the proper utilization of these methods, their relationship with other audio visual aids, and how they can be coupled with them have been effectively developed.

1 John S. Richardson, and G.P. Cahoon, Methods and Materials for Teaching General and Physical Science, pp. 9-12.
2 Dale, op. cit., pp. 42-49.
3 Hass and Packer, op. cit., p. 135.
From the discussion presented by this section and the previous one, it can be concluded:

1. That the audio visual element is very essential for proper abstraction and concept building, specially in general science that depends mostly on observation and sense perception;

2. That general science can benefit from the use of audio visual materials, probably more than any other school subject;

3. That concrete and contrived audio visual methods and materials can supply a variety of meaningful experiences which can enable the child to see the concrete background of the abstract concepts in general science and make him capable of using these concepts for further abstractions and generalizations.

(iii) A statement of the problem.

The aim of this study is to compare two approaches to abstraction or concept building; the one by a verbal approach to diagrammatic forms used in the teaching of general science; the other by an audio-visual approach to the same diagrams.

Diagramatic forms, e.g. chart, "diagram", poster and map are visual symbols which communicate ideas through a combination of drawings, words and pictures. They are generally made up from lines and geometric forms. For the purpose of this study the words "diagram" or "diagrammatic"are used to stand for what is popularly known as the diagram and the chart in the teaching of general science.
Probably general science depends upon the diagram as a tool of teaching more than any other subject. In every secondary school laboratory, diagrams of electric circuits, of different chemical apparatus used in the lab., of cross-sections of leaves and roots, of reflecting mirrors and refracting lenses are seen and drawn every day from chalk-boards, from science textbooks, from commercially made diagrams, or from actual apparatus or other objects.

Unfortunately this effective visual tool is not always properly used in science teaching. This fact is specially true of the country where this research work has been performed. A great many of the diagrams utilized in general science are highly abstract. The diagram is a visual symbol of the real thing; in general science most of the diagrams in biology and chemistry are not only visual symbols of reality but also visual symbols of the cross-sections of the real thing. In physics diagrams at times include symbols that do not look like the real thing. Whether it is for the sake of simplifying the process of drawing the real thing, or whether it is because the real thing is too abstract to be drawn on paper, visual symbols representing ammeters, voltmeters, rehostats, sound and light waves and magnetic lines of force can make the diagram a very abstract visual aid.

At times, diagrams used in general science teaching are made to look more confusing to the learner by the rough chalk-board drawing of the impatient teacher, the improper utilization of shading and colour, or other shortcomings in verbal and visual presentation.
As we have noted from the previous sections, abstraction, concept building or generalization in their simplest form, are a process by which an organism develops a symbolic understanding from a number of concrete and direct experiences to which he is subjected. It is therefore a waste of time to present the younger learner with a highly symbolic representation of reality (the diagram) and then expect him to proceed in the process of symbolism without having an accurate understanding of what refrents these visual symbols stand for.

To test the student by asking him to reproduce the diagram or the information presented by it may not be a proof that he has developed correct concepts from it, or that he is capable of using these concepts for further abstractions. In the previous section it has been stated that a child can use a concept correctly in his conversation without really fully understanding what it means; in the same way a student of science may produce very good labeled diagrams in his final exams without really having made satisfactory abstractions from what he is drawing.

Accordingly, to make sure that children have formed the concepts the science teacher wants them to build, it is often advisable to introduce the information of the diagram by the help of concrete and pictorial audio visual aids before bringing the diagram into the scene. Generally the real thing presents a better audio visual aid than the semi-concrete one, but, as explained in the last section, the contrived or pictorial audio visual material may be better in showing the concrete
background of the diagramatic symbols.

It may be advisable, at this stage, to mention some of the widely-held criticisms of audio visual methods, since some of them at least are fairly connected with the main object of this study.

A frequent criticism of some audio visual materials, e.g. the motion picture, is that learning from them is passive and hence their use interferes with the development of concepts. Research studies in visual education have proven the opposite.\(^1\)

A pertinent criticism is that an excess of enthusiasm for audio visual instruction on the part of the teacher may result in confusing the learner. It is reasonable to point out however, that this over enthusiasm is a shortcoming of the teacher rather than the aids to teaching; although it must be admitted that the teacher who chooses to run riot in the audio visual field has greater opportunities for doing so than in almost any other branch of his teaching.

To restate the aims of this experimental research in the light of the fore-going discussion, it can be stated that these objects are:

1. To compare the processes of abstraction from the verbal and the audio visual channels to the diagram in science teaching.

2. To throw some light on the complex process of abstraction and concept building at large.

3. Considering that the diagram itself is an audio visual aid, the whole research work can also be viewed as an experimental

\(^1\) Encyclopedia of Educational Research, 1960. p.47
comparison between the teaching of general science through one audio visual aid as compared with teaching it through the use of more than one audio visual material.

(iv) Review of the Pertinent Literature

An investigation of the available literature shows that although a considerable amount of research has been done in audio visual instruction, most of it has been about the projected motion and still picture. This fact marks a misunderstanding of audio visual education at the scholarly level. Educators have always been reminding teachers that audio visual instruction is not simply the use of the cinema or the filmstrip in the darkened classroom. They claim that such a one-sided view of audio visual instruction can only result in a failure to see the values inherent in the use of numerous other concrete and contrived aids; audio visual research workers, by compiling their studies in the projected visual forms have committed the same misconception.

Probably the diagram has the least attraction for visual education research workers. To clarify this supposition, the Encyclopedia of Education Research\(^1\) indicates that no worthwhile research study about diagrammatic forms has been reported between the years 1933 and 1947, and that between the years 1947 and 1960, the works of only four researchers have been cited.

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\(^1\) Encyclopedia of Educational Research, p.121
Most of the experimental work about audio visual aids, even the projected pictorial materials, is concerned with factual information, retention and perceptual-motor skills; very sparse studies have been performed about the relation of visual material to concept formation. Indeed, with the exception of the work done by Piaget and his collaborators, which has been severely criticised by modern psychologists, studies about abstraction and concept building have, for the most part, been limited in scope even in its natural field of psychology.

This research study compares abstractions from the diagram with abstractions from other audio visual aids plus the diagram. Accordingly, it is the work of audio visual educators about abstractions from one or more audio visual materials, or the studies of educational psychologists about the role of the visual impact in concept building which would be relevant.

The following are among the very few research studies done in this line:

The Forty-Eight Year Book of Education\textsuperscript{1} reports an article by Edgar Dale, James D. Finn and Charles Hoban in which, after sifting various research studies sponsored by the American National Education Association, and other prominent audio visual experts, they have distilled a summary of what Edgar Dale\textsuperscript{2} calls the "proven contributions of audio visual materials." Three of these contributions which are

\begin{flushleft}
\textsuperscript{1} Forty-Eight Year Book of Education, N.S.S.E., p. 254.
\textsuperscript{2} Edgar Dale, \textit{op. cit.}, p. 65
\end{flushleft}
pertinent to this study are:

1. They (audio visual materials) supply a concrete basis for conceptual thinking and hence reduce meaningless word responses of students.

2. They develop a continuity of thought; this is specially true of the motion picture.

3. They provide experiences not easily secured by other materials and contribute to the efficiency, depth, and variety of learning.

In the field of general science teaching, Rulon found that the use of the film with the text-book as compared with the text-book alone has improved the ability of children in the application of a concept or the inferring of a fact from another. This was proved by an immediate as well as a delayed test.

In 1944, Meredith conducted an experiment in four Exeter secondary schools in which he critically compared the visual and aural methods of teaching general and social sciences. Films and large still pictures were used in the visual methods. By using his novel technique of "Topic Analysis", he concluded that visual methods were superior to verbal methods in the apprehension of observational facts and diagramatic representations, and inferior in the apprehension of vocabulary and inferences.

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He also proved that the use of the "paragraph film", or the cutting of a film into short segments of two or three minutes duration, to be much superior to either the purely verbal method or the visual method in which whole films were shown at one instance. Probably this "paragraph film" method gave the children more time for conceptual thinking and reduced the possibility of boredom and fatigue.

By comparing a sound film about American cow-boys with long and abbreviated versions of a film-strip dealing with the same subject, Carson\(^1\) reported a study made by the Scottish Educational Film Association, the results of which verified that the film-strip groups were greatly superior to the film groups in both factual knowledge and the development of concepts.

Similarly, Slattery\(^2\) compared the effectiveness of a sound film and a silent film-strip in the conceptual learning and factual information of Grade V social science. She found the film-strip to be significantly superior with or without student participation.

An interesting study about the effect of the third dimension in concept building and factual information from coloured slides


was performed by Vergis.\footnote{John P. Vergis, A Class Experiment Designed to Determine the Effectiveness of Projected Three Dimensional Still Pictures. Doctors' Thesis. U. of Southern California, 1954.} Though the addition of the third dimension had no effect upon learning situations that were not dependent upon depth of cues, it proved itself greatly superior in influencing the interpretation of form and size in space. He has accordingly concluded that pictorial 3-D projection is best suited for the communication of such special concepts.

From a series of studies and articles about graphic and diagrammatic materials performed in England, Vernon\footnote{M.D. Vernon, "Presenting Information in Diagrams." Audio-Visual Communication, R.I.: 147-58; 1953.} has produced the following summary of conclusions:

a. That readers require special training to enable them to understand graphic materials properly,

b. Placing information in diagrams does not insure that the material will be understood ....

c. Certain types of data require certain types of diagrams

d. People understand diagrams better when they are accompanied by verbal explanations.

In the field of educational psychology, Heidbreder\footnote{Edna P. Heidbreder, "The attainment of concepts; III the process". J. Gen. Psychol. 24:93-138; 1947.} found that concepts develop more easily from pictorial forms than from verbal material and that the more concrete the items conveyed by the picture are, the easier will conceptualization be.
Brownell reached similar conclusions in his research work about the attainment of basic arithmetical concepts.

Flanders on the other hand came to the conclusion that, for the development of concepts, as children grow older, it may be more advantageous to use concrete experiences plus verbalization.

These are some of the few research studies done by visual education experimenters and psychologists in the field of conceptualization from visual representations. It is evident that these experiments have been performed under very different conditions, utilizing a variety of experimental designs, using different visual aids, presented in various ways, analyzing their results by different methods, and hence reaching conclusions that in many cases can only represent the very situations under which the experiment has been carried out.

It will be seen in chapter II, that in the scope of teaching methods, and the audio visual methods in particular, there is no systematic and agreed specification of the large number of the existing variables, some of which may be very difficult to control.

Nevertheless, it may be safe to make the following broad conclusions from the foregoing and similar studies about abstraction from visual materials:

a. that concepts evolve more easily by the help of concrete and contrived audio visual aids.

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b. that as far as pictorial visual materials are concerned, there may be some advantage in slowing down the presentation to give the children enough time for abstraction.

c. that in conceptualization the use of more than one visual aid may be superior to the use of one visual material.

d. that putting information in diagrammatic forms does not insure that the learner will understand them or develop concepts from them; diagrams, due to their abstract nature, require special training and preparations before presenting them, and an adequate verbal explanation after bringing them into the scene.
CHAPTER II.

THE DESIGN OF THE EXPERIMENT.

(i) A summary of the design.

To investigate the problem of this study experimentally, suitable general science topics taught by the help of charts and diagrams are chosen. Matched groups of bright, dull, younger and older children are selected. The experimental groups are introduced to the diagrams and charts of the science topics through the utilization of other, more concrete, audio visual materials, while the control groups are given a verbal approach to the same diagrams and charts.

Some time after the teaching of the topics is completed, a specially constructed abstraction test is given to all groups to bring out any differences in conceptualization which may exist between the visual and verbal groups.

(ii) Choice of Topics.

Upon the suitable choise and teaching of the above topics depends the success or failure of the whole experiment. Lessons that are too difficult, too easy, unsuitable in length or uninteresting to children can hardly produce any reliable conclusions however efficient the method of statistical analysis the experimenter follows.

Studies like this one in hand, which seek to measure highly refined differences, require that the topics taught should have some degree of novelty and diversity. The past experience of students about a familiar topic can ruin the whole experiment. On the other hand, if the teaching
of the topics chosen should take much time, their content must not be very much different from what the children are going to study in future. This will minimize artificiality and waste of children's time.

Hence, bearing these points in mind, much time has been devoted to the selection of the following five topics and the audio visual materials to be used with them. These topics are taught by the help of twelve diagrams and charts:

a. Blood.
b. Food and digestion.
c. Levers.
d. Shadows and eclipses.
e. Soap making.

A detailed account of these topics will be given in chapter III.

(iii) Choice of students.

After the content of the topics had been arranged in the form of forty-minutes lessons, the diagrams prepared in the form of large wall charts, and the various audio visual materials selected and improvised, a pilot experiment was performed in an English School, the Lansdowne Secondary Modern Boys' School at Leicester.

Even though the Headmaster and the science teacher stated decisively that the children chosen for the pilot research had not studied any of the topics mentioned above, it was found that many children knew so much about these topics as to spoil the inductive
problem-solving approach planned by the experimenter to motivate the students. For example, a good number of boys knew enough about the structure of blood, the process of digestion, and the propagation of light, so that questions like "what makes blood red in colour?", "what happens to food when we eat it?", or "what causes shadows?" could hardly present a problematic situation.

This phenomenon may be attributed to the English decentralized system of education that does not bind the teacher with hard and fast syllabuses. Thus children coming from various schools may have quite different educational backgrounds.

It may also be due to the increasing number of attractive general and social science children's books, to the highly mechanized society in which English children live in, and to the growing popularity of children's and school Television Programmes. The great role played by Television in conveying scientific information vigourously to children has been illustrated by Holmes\(^1\) who came to the conclusion that Television favours the teaching of science more than other subjects and that Television students at home do as well or even better than students in conventional classrooms.

Another outcome of the pilot experiment in Lansdowne School was about the reaction of the English children towards audio visual materials. It was felt that though the use of audio visual aids in

presenting the digrams had made the class-sessions more interesting
to both the boys and the teacher, and had increased student partici-
pation, the reaction of the children was rather sophisticated. Audio
visual materials did not present a novel medium of instruction to
them. English children are used to seeing films, filmstrips and
models conveying scientific information.

Accordingly it was concluded that to measure such an intricate
subject as the effect of audio visual materials in facilitating
abstraction from the diagram, children who have not been subjected to
much use of visual aids might have produced a better measure.

On top of these two main problems, other difficulties concerning
the availability of the large number of children who can spare the
time for all the five topics, the difficulty in securing the co-
operation of teachers and headmasters, and the unfamiliarity of the
experimenter with English children, English syllabuses and educational
system have been anticipated. After some discussions it was decided
that the Sudan might be a much more suitable place for doing this
research.

Sudanese children do not study any science until they complete
their Intermediate (8th grade) education at the age of a little over
15 years. The school curricula are highly centralized by the
Ministry of Education. So it is quite an easy matter to tell what
children have studied in each stage of their educational ladder.

Though science is taught in English, children are not familiar
with the modern simplified science literature published for children. In fact, even libraries do not usually stock them. No Television service has yet been introduced in the Sudan and the Radio is not used for furthering science teaching in secondary schools. The Sudanese society being comparatively under-developed, the school textbook and the science teacher's lectures and lecture-demonstrations are thus about the only channel of science education. Hence the problem of previous knowledge which the child can acquire through formal education or from the outside society is reduced to a minimum.

Audio visual aids to science teaching are very rarely used in Sudanese schools. To most of the secondary school children the use of a projected image onto a screen can only mean a feature film show in the city centre. In an unpublished M.A. Thesis, Audio Visual Aids for Improving Science Teaching in Sudanese Secondary Schools, it was found that the chalkboard, textbook, and wall chart diagrammatic forms and the demonstration are about the only visual materials used in Sudanese secondary science teaching. About the use of audio visual instruction in Sudanese Primary Schools the writer says, "The only visual aid, which is very much misused, is the blackboard constructed from plywood or is simply a black wallboard ... The only 'visual aid' which the teacher usually takes with him to class is the whip; an important aid in killing any form of socialized class procedures".\(^1\)

\(^1\) M. Bedri, op.cit. pp. 86-93.
This sparse use of audio visual materials though unfortunate to students, presents a very favourable situation for this study. The novelty of audio visual forms will thus show more clearly whether more concrete audio visual materials can improve conceptualization from the diagram in science teaching, and whether the age and intelligence of the child has any positive or negative effect in such abstractions.

(iv) **Choice of schools and age groups:**

After it was decided that the experiment be done in the Sudan, the choice of the secondary schools presented no problem. The Ahfad College comprizing five streams of secondary schools arranged as to their academic intelligence,\(^1\) is the only institution in the country that has such a wide range of secondary student population. The author who has been a science teacher in this college for the last ten years, and who is accordingly more familiar with Sudanese children and educational system, had no difficulty in securing the co-operation of the Principal and the science masters. Being a private institution, the fitting of the topic lessons in the school timetable of the classes taking part in the research did not require the interference of any authority outside the college.

The selection of the age group for this study was influenced by three factors. First, the children chosen should be mature enough

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\(^1\) Intelligence tests are not yet introduced in the Sudan. Children are divided into brighter and duller groups by State centralized Examinations in all subjects by which those who succeed are transferred from the Intermediate to the Secondary schools.
to understand the concepts conveyed by the topics. The pilot experiment has indicated that twelve-year-olds may not easily comprehend concepts involving mathematical and perceptual abstractions like the law of moments in the lever and the phases of the moon in the topic "Shadows and Eclipses." Second, children must have studied a little general science that would give them a broad background for the information to be supplied by the topics. The third factor is that the content of the topics should not have been covered at a previous occasion, at least not in any detailed form.

(v) System of sampling and control followed:

(a) System of Sampling

According to the three factors influencing the choice of the age group mentioned above, and the time allowed for doing the practical part of this research, two second and two third year classes were selected. They had an average age of sixteen plus and seventeen plus respectively. In each case, the brightest class and the next brighter class have been designated. This selection has been done in this way to provide the experiment with a sample containing older, younger, more intelligent, and duller children.

Classes in the Ahfad schools consist of about forty children, but, for the purpose of this study, thirty-six subjects from every class have been grouped. Each one of the classes selected has been divided into an experimental visual group and a control verbal group.
of eighteen boys. Hence the total sample of 144 students has been arranged into eight groupings of which four are experimental visual groups of bright older, dull older, bright younger, and dull younger children, the other four carefully matched control oral groups.

Though the difference in age between the second and third year classes is only about twelve months, no way of increasing this difference, and hence overcoming this weakness in the experimental design could be brought about. It was found that out of the four grades of the secondary education, second and third year boys present the only age group suitable for the study.

By trying out some of the lessons with first year boys, it was quite evident that they had not acquired enough science to give them the necessary background to grasp the elementary information of the topics, let alone further abstractions from the diagrams. Fourth year boys on the other hand have studied the content of three experimental topics in detail.

However, though this small difference in age may handicap the conclusions to be drawn from this study, its significance must not be under-estimated. There is a strong evidence that the mental ability of a child continues to develop till he reaches the age of twenty and even beyond.¹ As for intellectual experiences, one

academic year of general science and related subjects will definitely make much difference to the growing Sudanese child to whom the school is about the only channel of scholastic training.

Since this study is not intended to formulate generalizations about the achievement of students as such by giving them special aptitude tests, or to measure the validity or reliability of special tests by giving them to a large cross-section of student population, but simply aims at comparing abstractions from two methods of teaching, a very large sample of children may not be as important as an efficient method of control and statistical analysis. It is accordingly hoped that the sample of 144 subjects, though small in number, can still yield reliable results through the help of the control and statistical devices followed.

(b) System of control.

The carry over of the system of control experiments from biological and physical to social sciences has supplied the field of education and psychology with a wealth of valuable information that might not have been collected otherwise.

However, the formal similarity between these two categories of sciences may have concealed the underlying differences between them. Thus many research workers in the field of education, by following the simple procedure of unadapted copying, have produced artificial experimental designs, and have accordingly formulated
superficial conclusions. Investigations by Philpott\textsuperscript{1} demonstrated how fallacious the arguments deduced from such experiments can be.

Researches in psychology and education cannot be conducted in the same way as experiments for comparing the effect of adding a special manure in the growing of potatoes, or the discovering of special genetic factors in drosophila flies. In the latter cases, all the variables are specified and organized. Hence an experiment can be designed to give the knowledge required in an exact form. Once an experiment has been successfully performed, and a plan of the steps taken, a repetition of the steps, under similar conditions, will produce the same results.

In the field of education and psychology on the other hand, there is no way by which all the variables can be controlled. In fact, as stated earlier in this study, there is no agreed and systematic specification of the existing variables; this is specially true of the new field of audio visual instruction.

This fact is probably the reason why the control group technique has been most successful in psychological experiments involving identical twins. In such cases, many of the variables produced by different forms of inheritance, which are uncontrollable otherwise, are completely controlled or at least brought down to a bare minimum, hence making experiments of this category very similar to research.

\textsuperscript{1} S.J.P. Philpott, "Fallacious Arguments from Experiments on Methods of Teaching". \textit{British Journal of Educational Psychol.}, 1945, 15, 57-69.
studies in physical and biological sciences. It is only after biologists succeed in discovering a method of controlling the human chromosomes and genes by which a 'mass production' of children having the same genetic construction, and physical scientists invent a machine by which those who are not genetically 'quite perfect' are detected and separated, that unadapted copying from physical and biological control experiments can be justified. But as conditions exist now, there is a natural confusion in the field of education and psychology which must decide its unique experimental designs and statistical analysis.

In his paper, *Qualitative Information from Control Experiments*, Meredith has given a very effective illustration of this natural complexity in the scope of audio visual research; he says:

... We are dealing with methods of utilizing materials to foster growth of knowledge in the minds of children. From one experiment to another, the children vary, the topics vary, the materials vary, the methods vary, and the teacher handling them varies. The modes of variation is highly complex. The introduction of a new method may provoke an excitement which gives transitory stimulus to learning which fades when novelty wears off but gives spurious advantage to the new method while it lasts.¹

To feel one's way out of this confusion, Meredith² suggests that a close qualitative appraisal of all the variables involved should be performed by the research worker.

In accordance with the preceding discussion, it may be said that an attempt has been made to plan the system of control employed in this research study in a way which is most suitable to the nature of the audio visual field of instruction at large and the scope of this study in particular.

Some of the audio visual education research workers, by unmodified reproduction from physical and biological scientific experiments, have over-estimated the control of some factors, e.g., the age and intelligence of subjects, to the degree of artificiality, and have under-valued, or even at times completed ignored, the control of other important aspects like the previous knowledge of children about the experimental topics utilized, the way in which the visual materials themselves are used, and the role of the teacher in influencing the results of such experiments.

It is hoped that the following account of the detailed methods of control followed in various aspects of this experiment will illustrate this criticism:

(I) The Control of Previous Knowledge.

The importance of the former experience of the students about the topics used in similar researches has already been discussed. In fact, as it has been explained in section (iii) of this chapter, the difficulty of controlling the scientific information that children have about the experimental lessons has been one of the essential factors that decided the choice of the country in which
this research has finally been carried out.

The pilot experiment in Lansdowne School has clearly shown that under the educational conditions employed in England and similar countries, new methods of control experimental approach should be designed if more reliable contributions are expected to evolve from educational research. It seems that as societies develop, and the channels of child education increase in number, it will become more and more difficult to keep control experiments to one variable. This fact may be one of the causes for the failure of many audio visual education studies in producing significant differences between visual experimental and aural control groups.

Though it is not generally expected of a Sudanese child who starts taking general science at the age of 15 plus, who does not watch any scientific Television programs, who does not live in a mechanized society, and who is not familiar with modern scientific children's literature to gain any scientific knowledge vicariously, a system of control for eliminating even this rare possibility has been devised.

It was decided that the teaching of the lessons should start by a short 'practical' background given to both the experimental and the control groups, after which the verbal groups would receive an oral approach to the diagrams, and the visual groups an audio visual presentation to the same diagrams. Figure (I), shows this plan in a diagrammatic form. The final abstraction tests have been made in
A common practical background to both groups

Verbal Approach

Audiovisual Approach

Verbal Groups

Audio Visual Groups

Fig. 1. A diagram showing the presentation of the topics.
such a way as to bring out any differences between the groups in those parts of the topics which have been differently presented to the aural and visual groups. After this general introductory background of demonstrations and lab work it is expected that students will start from the same footing. Any differences that the tests show can thus be more confidently attributed to the different methods of teaching employed.

Besides making the system of control more efficient, this practical background of scientific demonstrations to all groups has another very essential value. Without it, the teaching of the aural groups would have become too verbal. Indeed, general science would have lost its uniqueness if taught only by the diagram plus chalk and talk.

However, it may be pertinent at this stage to mention another weakness in the experimental planning of this study which if noticed and corrected before it was too late, might have greatly improved the significance of the conclusions to be drawn from this experiment. After finishing the introductory practical base given to all groups, a test should have been performed before proceeding to the next step of giving different methods of instruction involving the use of the diagrams. The results of this test could have provided a very good check for the system of control followed, and it would have conclusively shown the differences in conceptualization when compared with the abstraction tests administered when the teaching of the topics have been completed.
This procedure might have taken this research work one step further, from a study of the first order to an experiment of the second order; that is, from an audio visual instruction research in comparing abstraction from the diagram in science teaching to a study in the methods of research in audio visual education.

However, this suggested design of dividing the experimental topics into two sections, giving the first part to all groups in the same way, testing, teaching the other half differently to the experimental and control groups, testing again, and comparing the results from the two tests, may be one of the answers for combating the difficulty of control already investigated.

Also, a more efficient design could have been obtained by switching the experimental and control groups when teaching the different experimental topics, and by giving repeated delayed tests. These two suggestions however would have required much more time and a larger sample if reliable results are expected to evolve from them; both these requisites were difficult to secure under the conditions this study was performed.

(2) Control of age and intelligence:

As was stated in section (v) of this study, a sample of 144 subjects from two second and two third year secondary school classes have been selected, that in each case the brightest class and the next brightest class have been designated, and that the choice has been done in this form to provide the experiment with a sample
containing older, younger, more intelligent and duller children.

Out of the forty students constituting the secondary classes of the Ahfad College, where the experiment was performed, thirty-six boys from each class were chosen. These thirty-six subjects were divided into an experimental visual and a control verbal group of eighteen children. Thus the total sample of 144 students have been arranged into eight groupings of which four were experimental visual groups of bright older and dull older third year boys, bright younger and dull younger second year children, and the remaining four carefully matched control oral groups from corresponding classes.

Because intelligence tests are not yet introduced in the Sudan, children are divided into brighter and duller classes by a State centralized Examination in all subjects by which it is also decided whether a student is capable of being offered a scholarship in Government Secondary Schools or not.

The Ahfad College, where this experiment has been performed, is the largest private educational institution in the Sudan. Many of the children who do not get high grades that would give them the chance to be accepted in government schools find places in the Ahfad, while some of the very bright children who have had their Elementary education in the Ahfad, prefer to continue their Secondary schooling in the same institution. Accordingly, it may safely be said that, as far as intelligence is concerned, this College, made up from five streams of secondary pupils, has the largest range of student population
in the whole country. Thus the difference between the brighter and the duller classes is much greater here than anywhere else in the Sudan. This difference is specially noticeable between the brightest class and the next brighter one (these are the classes chosen for the experiment). As one goes down the ladder of intelligence, the differences between the classes tend to diminish.

Though it is not always as valid and reliable as it should have been, the State Centralized Examination is a very good measure of the student's academic intelligence. In fact, very few students indeed manage to get from a duller to a more intelligent class, or regress from a brighter to a duller class during the four years they spend in their secondary education. Even in these rare cases, the shift can almost always be explained. This may be due to the fact that children take this exam at the age of 15 plus when the curve of intelligence starts to taper off.

Thus the Ahfad College's system of classifying students into more intelligent and less intelligent, which depends upon this State Exam and other local final tests by which children are transferred from one class to the next, has been accepted as the system of grouping the two second and two third year classes selected into brighter and duller children.

As for the division of each class into an experimental and control groups, students have been paired as to their average in the last two general science term examinations before the experiment.
This was done by the experimenter himself. Then the science master of each class chosen was asked to divide his students into two matched groups from his own point of views without seeing the lists prepared by the experimenter. After he has done that, the two categories of lists were compared, differences between them discussed, and a carefully matched system of experimental and control groups arrived at.

At this stage four to six students from each class have been excluded from the experiment to bring the total of each class to thirty-six subjects of eighteen boys in each experimental and control group. To keep things natural, the excluded children were not informed; they attended the experimental lessons and took the tests, but their answers have been eliminated. This 'trimming' was very helpful in the cases where the experimenter, who has taught most of these children before, and the science masters could not reach a favourable agreement about the pairing of certain students. It was also very helpful in the control of age. Those who were too old or too young to be matched have been kept out. In two separate cases, however, two of the excluded children were re-admitted to fill the gaps of two absentees.

As a matter of fact the control of the children's ages produced no problem. According to government regulations, children are not allowed to start school education before the age of seven plus. Hence, almost all the boys in the selected third years were seventeen
plus, and almost all the students in the chosen second years sixteen plus. This homogeneity in age is however limited to the brighter classes of the College of which the four classes designated for this experiment are a part. Boys in the duller classes are generally more heterogeneous in their ages since a good many of them have 'repeated the year' twice or thrice before coming to the secondary school.

At any rate, the over-estimation of the age-factor of children taking part in such experiments may be considered as an unnecessary means of control. Trying to pair the ages of subjects to the nearest month is simply a misconception of the field of education. In dealing with drosophila flies in a genetic experiment, a few hours may be of extreme importance, but when working with human experience and intelligence, the concept of mental age may make a bright thirteen year-old, older than a sixteen year-old.

Even the over emphasis of the importance of the I.Q. to the extent of trying to equalize children to the nearest score, may itself be a misunderstanding of the nature of experimental research in education and psychology. The intelligence tests, even when valid and reliable, are composed of several questions measuring different aspects of intelligence, the sum total of which is the child's I.Q. A specific topic in general science or any other subject may be depending upon one of these factors of intelligence or the other. Thus even if every child in the experimental and control groups has exactly the same I.Q., this may not be a proof
that the children's capabilities concerning the specific experimental
topics in question is going to be identical, or even very much
similar.

This being the case, the paring of students as to their
abilities in dealing with specific subjects may at times give a more
superior method of control concerning the teaching of experimental
topics, in that specific subject, than a general intelligence test
involving a wider sphere of knowledge and other tasks.

Also, the view of the teacher of a specific subject about the
academic standing of a child in that subject may be more reliable
than the scores of a quick test which is usually administered under
unnatural conditions and nervous strains.

So, though the absence of I.Q. scores in the system of intelli-
gence control may be considered as one of the design weaknesses of
this study, it is hoped that the methods of control described in this
respect will prove to be more suited to the field of the research,
more accurate and hence more rewarding.

(3) Control of the efficiency of teaching methods:

In many of the research studies in which audio visual materials
seemed to be beaten by chalk and talk, the inadequate system of con-
trolling the efficiency of teaching methods may prove to be the
reason. In most of these cases, though the experimental and control
groups may be very well matched as far as age, intelligence and such
factors are concerned, the control verbal groups, after receiving
properly prepared verbal lessons, will be compared with the experimental visual groups which has been taught by audio visual materials greatly mis-utilized.

Audio visual materials, like a variety of new inventions and tools improvised by man, need a special technique of utilization if they are expected to give the results they are supposed to give.

Some tools of the surgeon are the scissors, the forceps and the knife. For each stage of a medical operation there is one correct tool to be used in only one special correct way. No one is allowed to use these tools without having previous medical training in their proper use. The failure of an untrained doctor in an operation is not to be attributed to these tools, but to the way they have been used. Similarly, the tools of the teacher are these audio visual materials. For each teaching situation there is an ideal visual aid which must, at least theoretically, be used by one best method. So, in most cases, the failure of the teacher to produce good results with visual forms should first be attributed to the improper selection and presentation of these materials before making any sweeping generalization about the whole field of audio visual instruction.

Audio visual aids are not developed as substitutes for the teacher; when properly utilized they will only increase his importance. A film or a set of slides used in the classroom should neither be a chance for the teacher to sit back and watch, nor should it be a substitute for the spoken word.
To be effectively used, for example, visual materials should be well selected in terms of the immediate and long-range purposes for showing them. They must be previewed and the teacher should prepare himself for any difficulties that might arise. Before showing the material the class must be physically and psychologically prepared for it. Seating is well arranged and difficult words and concepts explained. The children must be told what to look for. After showing the material the teacher is expected to follow the visual experience by oral or written tests, by further audio visual aids or by other means of activities and evaluations.

In examining the research studies made in the audio visual field in the light of the foregoing discussion, a good many of their experimental designs may prove to be inadequate in this respect. In many cases, research workers comparing visual and verbal methods of teaching would give teachers, unfamiliar with audio visual instruction, a quick 'brush up' about the visual materials to be used with the experimental groups, ask them to perform the experiment, and then they will sit back to analyze the 'poor results' of the visually taught children.

In some cases, the experimenter himself, for one reason or the other, may deliberately mis-utilize the visual material. Examples of this case may be illustrated by such studies as the one done by Noel and Winget\(^1\) in which they compared the proper utilization of

conventional methods of teaching physics against the use of physics films with inadequately prepared instructors and ill-equipped laboratories. Vander Meer performed a similar research to investigate the possibility of 'substituting' the teacher by the motion picture. The masters teaching the visual groups, instructed exclusively by films, did nothing for a full semester (four months) other than taking roll and maintaining order!

Such experiments, in which the experimenter intentionally or unintentionally misrepresents visual aids, even though they may, at times, give very interesting conclusions, do not really give the results of aural versus visual teaching; they merely show how verbal methods, properly utilized, can sometimes beat the misuse of visual materials.

This being the case, it was decided that, in order to bring the factor of the teaching efficiency of different groups under control, the experimenter, who is expected to know more about the use of visual materials than other science teachers in the Ahfad College, should do all the teaching of both the experimental and control groups himself.

Other than making an effort to equalize the teaching of the various groups, the 'self' teaching of the topics of this research proved itself most useful in another respect. Teaching is an active two-way process of interaction between teacher and learner. Hence,

many of the reactions of the class detected by the experimenter as he taught the topics, which in later stages has influenced the analysis of the results of the tests, might have been overlooked as minor detailed points, by other science teachers who naturally do not know the detailed data and aims of the research.

It was also decided that, to equalize the teaching efficiency of the verbal and visual group, a method whereby the best way of presenting the visual aids with the diagrams should be found.

Planning an adequate method for verbally explaining a diagram may be much simpler than preparing a similar plan for an audio visual approach. After all, teachers are all the time experimenting with words to find the most suitable methods of verbally explaining diagrams, but very few would take the pains to do the same with visual aids. In fact, as stated in the last chapter, even the research workers who have done any reliable work with more concrete audio visual aids to the diagram, may not exceed ten experimenters. Hence, trying to discover the most suitable methods of presenting the visual materials with the scientific diagrams of this study may be of paramount importance.

But to find the best method of presenting these audio visual aids in a proper way, may consume the time and efforts of another thesis; thus, to be fair with the visual experimental groups without loosing much time, a 'crude' experiment for solving this problem was carried out with the pilot research in Lansdowne Secondary School.
In teaching the five topics, the visual materials were presented in five different methods with the diagrams, namely before the diagram, simultaneously with the diagram, after the diagram, before and after the diagram, and the diagram itself presented before and after the visual aid.

Though testing for the proper abstraction of the information presented by the diagrams was performed by oral questions only, it was very clear that on the whole children need much more explanations to see the intricate connections between the diagram and the visual aids explaining it.

It seems that they often see the visual aids as an interesting way of a change from traditional teaching and the diagram as something 'solid' to study separately for tests, and so they fail to see all the relations between them. This is inferred from the fact that those who saw the diagram before the visual aid and after it, those who saw them simultaneously, and those who saw the visual aid before the diagram and after it, did better in the oral tests than those who saw the diagram only before the visual aid or after it, since they failed to see all the connections between them.

Though this procedure may be described as a crude way of arriving at conclusions, even if it concerns only a minor part of the experiment, it was evidently the only possible way to follow under the conditions in which this research was carried out. However, the author believes that these findings, with all the defects in its oral system of testing, if followed up by more research work,
may turn out to be one of the more valuable conclusions of this study.

So the findings of this pilot research were taken into consideration when finally presenting the diagrams to the experimental visual groups.

Trying to equalize the efficiency of teaching all the groups is not as simple as it may appear at first sight. Even though every effort was taken to control this aspect, it is known beforehand that complete control, without upsetting the natural methods of classroom-teaching, is almost impossible.

An educational research worker following a lesson plan in teaching an experimental topic is not like a scientist who follows special steps in performing an experiment in chemistry or biology. In the latter case, any one following these steps under similar conditions is bound to get exactly the same results. In the former case, it is almost impossible for even the same master to teach two classes in an identical form, even if he follows the same plan and uses the same teaching materials. Any one with any teaching experience knows that when teaching a lesson for the second, third, or fourth time, he may feel that he is becoming like a tape recorder, but he will definitely know for sure that every time he repeats the lesson, it will be different from the previous one in teaching. His presentation may be improved every time he repeats it since he may
gain more and more experience, or it may be inferior because he starts to get bored from this continual repetition.

Other variables like the time at which he gives the lesson, unpredictable favourable or unfavourable student activities, the teacher’s own mood, and other variables about the type of materials used and how they are utilized may all have a positive or negative influence on the effectiveness of his teaching.

This illustration involves the teacher trying to equalize his efficiency of teaching the same lesson to more than one class. From this it can be visualized how difficult it would be to try to completely control the effectiveness of teaching two categories of children in two different teaching methods, utilizing different teaching materials.

(vi) Statistical Analysis followed:

One of the most difficult problems facing a research worker in education is the choice of a method of statistical analysis appropriate to the scope of his research topic. Thus, to spend some ten hours collecting data in a school and about one hundred hours analysing these data, would appear to be a misuse of statistics as an aid to educational research. It seems that in such researches, statistical methods cease to be a means of arriving at reliable conclusions and become an end in themselves, thus making the collected data a secondary factor in educational research. This is probably another result of unadapted copying from other sciences.
In his book *Statistical Methods For Students in Education*, Holzinger has given a very effective account about such deliberate or unintentional misusages of statistics in educational research. He states:

... It frequently happens that the worker loses sight of that his data are inadequate as to quantity and quality and applies elaborate statistical methods with the expectation that the final results will be of value. Such procedure, if followed intentionally, has been rightly described as "hiding behind a statistical smoke-screen", and is nothing less than a scientific crime. The limitations of the data employed should always be frankly recognized and the conclusions of the study made with them in mind. No amount of subsequent juggling by complicated formulas can give good results when they are based upon originally faulty data.

... It is so easy to gather a few figures and tabulate them in such a way as to show a desired result or "prove" a certain theory that the temptations on the path of scientific rectitude are great. The untrained reader often so bewildered by tables and diagrams that he is incapable of verifying the method of the inferences in a statistical article and either accepts the conclusions on the reputation of the writer or perhaps concludes that "anything can be proved by statistics". Educational science would be greatly improved by the production of a smaller number of studies based upon better data and a more cautious use of statistical method".¹

It is probably this "hiding behind statistical smoke-screens" which motivated Philpott² to make his famous investigations on a much-quoted research with films, performed some years ago, pointing out serious fallacies in its statistical analysis, and hence showing how dubious such researches can be when statistics are used to curtail

¹ K.J. Holzinger, *Statistical Methods For Students in Education*, pp. 4-5.
² J. Philpott, *op. cit.* pp. 57-69.
weaknesses in their data and experimental designs.

Accordingly, to refrain from the misuse of statistical methods, and hence proceed in the same plan of avoiding artificiality and unadapted reproduction from other sciences, which was already followed in the system of sampling and methods of control, the simplest form of statistical treatment required to analyse the results of this experiment was used. It is thus hoped that this study will stand Holzinger's suggestion of "... a better data and a more cautious use of statistical method".\(^1\) Hence the reader will not be in need of any 'search-lights' or 'masks' to penetrate 'smoke-screens' in order to decipher unnecessary complicated formulae to test the reliability of the conclusions extracted from this experiment.

In fact, the nature of the study itself, and the kind of results obtained did not require that much of statistical work to arrive at the main conclusions of the experiment. The simple calculation of the mean scores and the plotting of the results in Meredith's "Item Distribution Charts",\(^2\) were about the only mathematical treatment of the results.

By making use of the experimental research work performed in similar scopes, some of which have already been described in chapter I,

\(^1\) K. Holzinger, *op.cit.* p.5.

\(^2\) The "Item Distribution Chart" is a simple effective mathematical technique for interpreting the results of experimental versus control groups, which was invented by Prof. G.P. Meredith and utilized by him in previous experimental researches.
this chapter has described the experimental design of this study. The reasons for the choice of the experimental topics, the students, the schools and the teacher have all been brought out. The systems of sampling, control and statistical methods followed have also been discussed.

The next chapter is intended to show how these plans have actually been used in the teaching of the five experimental topics.
CHAPTER III.

PRESENTATION OF THE EXPERIMENTAL TOPICS.

Before discussing the presentation of the experimental topics, it may be useful to sum up some of the major issues in the last chapter that have a direct bearing on this section.

As it has been mentioned, five general science topics, namely, "Food and Digestion", "Blood", "Shadows and Eclipses", "Levers", and "Soap Making", which are taught by the help of twelve diagrams, were selected. The total sample of 144 students was divided into eight groups of bright older, dull older, bright younger, and dull younger, experimental and carefully matched control groups of eighteen subjects in each group. All these experimental and control groupings were taught by the experimenter himself.

As a means of controlling the previous knowledge of subjects about the topics, and a system whereby, even the verbal groups were not deprived of the practical methods by which general science is commonly taught, a short background of practical demonstrations, generally including no diagrams, was given to all students. After this common base, experimental groups received an audio visual approach to the diagrams, and the control a purely verbal presentation to the same diagrams. The methods of presenting the visual materials with the diagrams to the experimental groups, has been deduced from the results of the pilot experiment carried out in Lansdowne School.
In the light of this summary, we may proceed to the more detailed presentation of the following experimental topics. They will be discussed in the order of their actual presentation to the Sudanese children; starting with the more concrete topics first, and giving the more abstract ones at a later stage, viz. "Food and Digestion", "Blood", "Shadows and Eclipses", "Levers", "Soap Making".

I. Food and Digestion:

This topic was taught in two double periods, each one 100 minutes duration, giving a total of three hours and twenty minutes for the full treatment. The topic was divided into four main sections:

a. Where does our food come from?

b. Types of food-stuffs.

c. What is digestion?

d. The digestive system of man.

The first three items were discussed in the first double-period lesson, and the other half of the time was devoted to the teaching of the fourth item.

The first section about the source of human food-stuffs was taught by the help of a diagrammatic chart, presented visually to the experimental groups and verbally to the control groups. Accordingly it was considered as a part of the topic where abstraction test questions will be concentrated.

The second and third items explaining the types of food-stuffs
and the concept of digestion were given as a common lecture-demonstration to all groups to prepare them for a detailed study of human digestion.

For the fourth section, the groups were again separated. The experimental groups studied the diagram of human digestion made concrete by two audio visual materials, and the verbal groups by a purely verbal approach.

For a more detailed presentation of the topic we start with the first item:

a. Where does our food come from?

I. The verbal groups:

Before seeing the diagrammatic chart shown in figure two, children were inductively guided to come to the conclusion that all human food comes directly or indirectly from plants. This was done by straightforward questions about tracing the origin of various Sudanese foods. Then the chart was brought into the scene and discussed in detail.

2. The visual groups:

The same inductive approach was used with the visual groups, and the diagrammatic chart was shown; but before doing a detailed study of it, a short filmstrip consisting of only five still pictures, from the children's own environment, which was specially prepared by the author for this occasion, was presented. Some of the frames of this
strip are shown in figures three and four.

Since the five frames of the filmstrip were practically a visual explanation of the diagrammatic chart, its detailed study was carried out during the showing of the filmstrip.

After the filmstrip exposition, the chart was shown again for quick follow up.

b. What happens to food when we eat it?

An experimental background to all groups:

I. Types of food-stuffs:

Different types of food-stuffs were discussed by the help of concrete examples brought into the laboratory. For example some eggs and meat represented proteins, some sugar and bread as examples of carbohydrates, butter and oil to make concrete fats, and fruits and vegetables to stand for vitamins and mineral salts.

2. What is digestion?

To explain the concept of digestion practically, the action of pepsin on a boiled egg and the action of ptyalin on starch were shown to all groups. The egg was boiled before the class-session and very thin slices of it, cut with a razor blade, were dropped into test-tubes containing warm pepsin, and similar slices placed in test-tubes containing water, as a control, was performed in front of the children, sometime before this issue was discussed. So, when students came to discover some facts about the concept of digestion, comparing the two samples,
Fig. 2. Diagrammatic chart showing that all human food comes directly or indirectly from plants.
We can get our food energy directly by eating plants...

And indirectly from animals living on plants in the following ways...
We can eat the meat of land animals...

...or their products.

Fig. 4. Some frames from the filmstrip about sources of human food devised by the author.
The diagram of the human digestive system.

Fig. 5. The diagram of the human digestive system.
clearly demonstrated that pepsin 'dissolved' some of the egg slices.

The action of ptyalin on starch was done by another control experiment in which, Fehling's solution boiled with some soluble starch made no change in colour, but when a specimen of the same starch was mixed with a student's saliva, boiling with Fehling's solution changed its colour to a brick-red precipitate.

These two experiments illustrate that digestion is a process whereby solid and complex food-stuffs are changed by the action of digestive enzymes into simple soluble compounds that can be absorbed by the body.

c. The digestive system of man.

I. The verbal groups.

The next step to the verbal groups was to be introduced to the diagram of digestion in the human alimentary canal (see Figure Five), verbally, and then to discuss it in detail. The action of the main digestive enzymes, the process of peristalsis, and the functions of different digested food-stuffs in the human body are explained. All difficult and new words were written on the board.

> 2. The visual groups.

Though the same content was taught to the visual groups, the diagram of the human digestive system was explained by the help of the actual digestive systems of two rabbits and a life-size model of the human internal organs. These aids were shown simultaneously with the
Some of the members of a visual group being introduced to the diagram of the human digestive system by the help of the large model of the human internal organs.
Figure 6 shows the members of one of the visual groups studying the diagram by the help of the model, with the actual diagram at the background of the picture.

The use of the visual aids with the experimental groups almost always aroused so much interest in the topics, at times, to the extent of putting the experimenter in an embarrassing and difficult situation, when trying to evade answering more detailed questions or trying to steer the discussion within the limits of the pre-planned experimental lessons.

II. Blood.

This topic was taught in three fifty-minute periods. Of these three periods, the first was devoted to an experimental background to all groups explaining what blood is, and what things constitute it. The remaining two periods, taken together, were used in discovering different facts about the function of blood in the human body. This was done by the help of a diagram and a diagrammatic chart, presented verbally to the control groups and audio visually to the experimental groups:

a. What is blood?

An experimental base to all groups:

What is blood? What makes it red in colour? Why is it slightly sticky and slightly salty in taste?!
To answer these questions inductively was necessary to give the children a good background to study the detailed diagrammatic chart shown in figure seven.

So, half a pint of blood was poured into a large bowl, and whipped with a stick to facilitate the continuation of clotting. This had been done some time before the class session. From the experience of the pilot research, it had been discovered that blood takes much time to clot, and with the limited time assigned for this lecture-demonstration, it would not be possible for the class to see the whole process. Also it had been discovered that some children get a squeamish feeling when they see such a big quantity of blood being beaten up.

Hence, after sufficiently arousing students' curiosity by questions similar to the ones sighted above, a sample of fresh blood was compared with the one in which clotting was completed, leaving a solid mass at the bottom and a clear yellowish liquid at the top.

This experiment explained that blood is made up from a solid 'thing' and a clear liquid. The value of blood-clotting to prevent death through loss of blood and the disease of hemophilia were quickly discussed.

A droplet of blood placed on a glass slide was examined under the high power of small microscopes distributed to the children, and later presented by the help of a larger demonstration microscope. A drop of ink diluted with some water was added to stain the cells.
This experiment explains what forms the solid part of blood. The differences between the red and white blood cells were brought out. By comparing their numbers, it was deduced why blood is red in colour. So, a general idea about blood as being constituted of a yellow pale liquid called plasma, which is made up from water with dissolved salts and digested food-stuffs, with a number of red and white blood cells floating in it, was formed. Of these floating cells, the red ones greatly outnumber the colourless ones, and so blood is red in colour.

b. The functions of the blood.

I. The verbal groups.

Since the functions of the blood are mostly the transport of various materials from one part of the human body to the other, an abbreviated introduction about the action of the heart in pumping blood through the blood vessels and capillaries has been given without getting into any details about the circulatory system.

Explaining the different functions of the blood, by the help of the chart and diagram shown in figures 7 & 8, was carried out in a simple language, giving as many examples from the children's past experiences as possible. This was specially true of the functions for which a sufficiently adequate background has not been supplied in the previous demonstrations or the previous topic about digestion.

When speaking about the transport of oxygen and waste materials, reference was given to the role of hemoglobin and the difference
between oxygenated and de-oxygenated blood. The carrying of waste nitrogenous materials from the intestine to the liver and from the liver to the kidneys was also very lightly discussed.

In explaining how white blood cells fight disease, it was mentioned that they do so by 'launching' a war against bacteria and 'eating them up'. It was mentioned that the whitish substance found in a neglected wound is made up from the dead bodies of the white blood cells that have lost their lives in such wars against 'invading' bacteria. Nothing about the way in which these cells eat bacteria, or how does bacteria look like was made clear. The reason for this will be given in later chapters.

About the role of blood in carrying chemical regulators, examples were given from two categories of hormones, namely, adrenalin as an illustration of a "quick action" hormone, and sexual hormones to represent those that have a comparatively slower and a more permanent effect. Both these examples of hormones proved to be of great interest to the growing Sudanese child.

2. The visual groups.

After an introductory survey of the diagrammatic chart and the diagram presented in figures 7 and 8, the visual groups saw a set of fourteen slides¹ explaining the diagrammatic chart in detail. These animated drawing slides were devised by the author specially for teaching.

¹ These slides have been animated by T. Garfield, the Geog. Dpt. Technician of the Univ. of Leicester.
Functions of the Blood

- Carrying of oxygen
- Carrying of food
- Carrying of waste materials
- Regulation of body temperature
- Carrying of chemical regulators
- Protection against diseases

Blood Plasma

Fig. 7: Diagrammatic Chart showing the functions of the blood.

Fig. 8: Diagram showing white and red blood cells.
I protect the body from disease.

This is done by the White blood cells that fight germs by eating them.

Fig. 9. Some of the slides about the functions of the blood presented to the visual groups.
Fig. 10. Some of the members of a visual group following up the film-slide presentation.
topic. Its 'cartoons' has been keyed with the six functions of the blood shown in the diagrammatic chart. Some of these slides are shown in figure 9. Accordingly, the detailed study of the chart, which was verbally done in a way similar to the control verbal groups, was performed in the darkened room.

After the slide-show, the chart and diagram were shown again as a follow up. Figure 10 displays some of the members of a visual group 'following up' after the film-slide presentation.

Of all the classes taught, it was quite clear that this film-slide presentation made this double-period the most interesting both for students and teacher, but how much value it had in facilitating abstraction will be discussed in later chapters.

III. Shadows and Eclipses.

Three fifty-minute periods were used in the teaching of this topic. The first period was utilized in giving an experimental background to all groups, explaining inductively that light travels in straight lines, and showing that this principle is the cause of shadows and the phenomenon of the umbra and the penumbra in shadows.

The experimental and control groups were then separated to receive different approaches in studying the formation of day and night, the phases of the moon, and the eclipses of the sun and the moon by the
help of four diagrams. This was done in the remaining two periods taken together. The presentation of the topic in a more detailed form is as follows:

a. How are shadows formed?

An experimental background to both groups.

1. By the help of a smoke box, all the groups were allowed to see how a pencil of light travelled in a straight line.

2. The principle of the pinhole camera was also demonstrated by a lighted candle placed in front of a pinhole in a cardboard with a small screen located behind the cardboard. By altering the distance between the candle, the cardboard and the screen, the students could see, in the partly darkened laboratory, how the image of the candle was affected by changing these distances.

Subjects eventually came to the conclusion that these two experiments prove that light travels in straight lines. To reach this conclusion a blackboard diagram of the pinhole camera could not be avoided.

3. The phenomenon of the umbra and penumbra.

A point source of light from a motor head lamp was obtained. It was demonstrated how when this source of light was used, sharp shadows, of even comparatively small obstacles, were formed on the screen.

These shadows were compared with the blurred shadows made by an opal lamp.
From this experiment it was deduced that a point source of light makes sharp shadows that are all "umbra", and that a large source of light produces shadows with blurred edges, made from an umbra of total shadow in the middle, and a penumbra of partial shadow in the peripheries. Groups were told that the law that light travels in straight lines is the cause of the phenomenon of the umbra and the penumbra and that its diagrammatic explanations will be dealt with in the next lesson.

b. Application of the Principle that light travels in straight lines to the formation of day and night, phases of the moon, and eclipses.

I. Verbal groups.

The verbal group was introduced to the diagrams shown in figures 11, 12, 13 and 14 verbally and then they studied them in detail. In discussing these diagrams, references were made to the principle that light travels in straight lines and how this fact causes the total and partial eclipses (umbra and penumbra) of the sun and the moon; this presentation can be summarised as follows:

a. Day and night.

Because light does not bend round corners, the face of the earth facing the sun will have day, while the face away from the sun will have night. (See figure 11).

b. The phases of the moon.

The light from the sun streams in straight lines past the earth
Fig. 11. The Formation of day and night.

Fig. 12. Phases of the Moon.
to illuminate that half of the moon facing the sun. The phases of that
the moon are caused by the fact/only a part of its illuminated half
can be seen from the earth. Figure 12 explained this phenomenon.

c. **Eclipses.**

i. **Eclipse of the sun.**

An eclipse of the sun is caused by a gigantic shadow of the
moon thrown on the surface of the earth, when the moon becomes inter­
posed between the earth and the sun. Accordingly, an eclipse of the
sun happens only when the sun, the moon and the earth are in one
straight line.

Because the sun is a very large source of light, the shadow of
the moon thrown on the earth's surface will have blurred edges (umbra
and penumbra). In some places of the earth's surface, the moon
completely covers the sun. This is the area of the umbra. At other
places, within the region of the blurred shadow, the sun is not com­
pletely covered by the moon. This is the area of the penumbra. The
region of the umbra is called the area of a total eclipse, while that
of the penumbra is called the region of a partial eclipse. Figure 13
shows how an eclipse of the sun takes place, and how the fact that light
travels in straight lines is the cause of the total and the partial
eclipses.

ii. **Eclipse of the moon.**

When the earth becomes interposed between the sun and the moon, its
shadow will be thrown onto the surface of the moon, hence it will be
Fig. 13. Eclipse of the Sun.

Fig. 14. Eclipse of the Moon.
eclipsed. If the moon lies fully within the umbra of the earth's shadow, it will be totally eclipsed. If on the other hand it lies partly within the umbra and partly within the penumbra of the earth's shadow, a partial eclipse will be the result. See figure 14.

2. The visual groups.

In explaining this part of the topic, the visual groups were presented with two simple models simultaneously with the diagrams. The main model is a working mock-up of the earth, the sun and the moon. This model is shown in figure 15, with the diagrams in the background. It is simply a table that rotates freely round itself, with a slide projector mounted in its centre, to represent the sun, and a globe fixed on a shaft which is nailed to the table to stand for the earth.

When the light of the projector is put on, the causes of the formation of day and night is very clearly shown. The globe is turned round its axis to 'move' the Sudan from day into night and vice versa. 'A few months' had passed by before every member in the class had a chance to make the globe spin 'a few days' around.

A tennis ball mounted on an elliptical wire, supported by independent wooden stands, presented the moon and its path round the earth. By moving the 'moon' in its elliptical axis round the 'earth', and looking at it from different angles, while the projector's powerful light was on, the phases of the moon could be very easily abstracted.

The shadow of the tennis ball on the globe illustrated the eclipse of the sun, while placing it, partially or fully, within the
Fig. 15. Studying shadows and eclipses 'visually'.

It seems the children find some difficulty when trying to visualize without the aid of concrete material, how the Moon which is
shadow of the globe, made concrete the eclipse of moon. The distance of the tennis ball from the globe, and the light of the projector were adjusted to produce the greatest area of penumbra to show the total and partial eclipses more clearly.

The second type of model was simply a number of "ping-pong" balls, with exactly half of their surfaces blackened by india-ink and soot. This simple model was very valuable as a second method of explaining the phases of the moon. The white side of the ball represented that face of the moon facing the sun, and the blackened side, its other face.

By holding the ball in a fixed position, stretching out his arm, and moving it round his body, the student could easily see why the full moon becomes a crescent, disappears, and starts to enlarge again.

In this connection, it may be of interest to note that in this topic, more than the other four, the difficulties in understanding, and hence in conceptualization, that the verbal groups faced, were almost nonexistent with the experimental groups. In fact, in most cases, the experimenter had to use a little bit more time to explain the phases of the moon and the partial and total eclipses to the members of the control groups, while, even with the two models utilized with the experimental groups, there was some spare time for a quick follow up of the diagrams.

It seems the children find some difficulty when trying to visualize without the aid of concrete material, how the moon which is
all the time only half illuminated by the sun, appears to them in such a great variety of shapes. A pre-fixed idea that the shadow of the earth is the cause of the phases of the moon, was one of the sources of difficulty that some of the students in the control groups had encountered.

IV. Levers.

Two lessons, fifty-minutes each, were utilized in the teaching of this topic. In the first period, all the groups received a lecture-demonstration explaining the three orders of the lever, and introducing the principle of moments.

For the second period, experimental and control groups were divided to study diagrams of some common applications of the lever through the usual two different methods of visual and verbal approaches:

a. What is the lever?

An experimental background to all groups.

By the help of a wooden beam (8 ft. x 4in. x 2 in.), some wooden blocks (to act as weights), a long nail, a string, and a large simple pulley, the three classes of the lever were demonstrated to all groups. The wooden beam had holes drilled at six inch intervals, so that it could rotate freely round when pivoted by the long nail.

By changing the distance of the load or the effort from the fulcrum of the wooden beam, and adding wooden blocks to balance the lever, the principle of moments was first explained in the first order
of the lever. This was done without going into any mathematical calculations. What children were asked to know was that the moment of the load or effort varies directly as the weight and the distance from the fulcrum of the lever.

Students found no difficulty in grasping this principle as applied to the first order of the lever, since they have more experiences with it in sea-saws, balances, "shadoofs"\(^1\) etc., but it took them more time before they could transfer the principle to the second and third orders of the lever. It is in such parts of the topics that differences in age and intelligence made themselves very much more marked.

b. Applications of the lever.

I. The verbal groups:

The second stage for the verbal groups was a verbal introduction followed by a verbal detailed study of the diagrams of the different applications of the lever shown in figures 16, 17 and 18. With the exception of the steam engines safety-valve, Sudanese children are familiar with all the applications illustrated in the diagrams. So, a more detailed discussion of the safety-valve was made.

2. The visual groups:

To the visual group, the actual applications utilizing the three classes of the lever were brought into the laboratory, to be

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\(^1\) The "shadoof" is a method by which the first order of the lever is used as a primitive simple machine for irrigation. First used by Ancient Egyptians, it is still found in Egypt and the Sudan.
Fig. 16. Applications of the first order of the Lever.
Fig. 17: Applications of the second order of the Lever.
Fig. 18: The applications of the third order of the Lever.
Fig. 19: Using the first order of the lever to lift a heavy piece of concrete. Audio visual materials are of great interest to both old and young alike. The little boy in the foreground, who has apparently found this sight more interesting than the Kg. conventional class-session, and old "Uncle Khojali", in the background, who has been a janitor in the college for the last 15 years, have been attracted by the outdoor use of visual materials. What sort of abstractions these two 'learners' have developed is certainly outside the scope of this research!
manipulated by the students and discussed by the teacher, simultaneously with the diagrams. Some of the applications which could not be brought into the classroom, e.g. the steam engines' safety valve and the human arm, simple cardboard models were presented instead. More direct visual aids used with the human arm, were some weights distributed to the boys, to put in their palms and flex their arms in such a way as to see whether their arms really represented a lever of the third order.

To see a wheel-barrow in work, students were taken to a building site in the college. After finishing from one of these trips, a group of these students are seen in figure 19 discussing the possibility of using the first order of the lever in lifting a very heavy piece of concrete.

V. Soap Making.

This topic was also taught in two periods. The first of these periods was a demonstration given to all groups, to give children a common background about the chemical nature of soap.

The second period was devoted to the different methods of studying a diagram about the large scale production of soap:

a. What is soap?

An experimental background to all groups.

Before the class-session, a large beaker containing some water was heated by a gentle bunsen flame till the water started to boil. When the students arrived they were told that they shall see a demon-
Fig. 20: Large scale production of soap.
stration of how soap is prepared in the laboratory.

Then, twelve ml. of 20% sodium hydroxide were mixed with twelve ml. of olive oil in a small beaker. The mixture was heated by placing in the boiling water, and holding the beaker in position by clamping it to an iron stand. One of the students volunteered to stir the mixture while the experimenter discussed the chemical reaction of soap making without using any chemical symbols or complicated detailed equations. The chemical equation used was as follows:

Alkali (sodium hydroxide) + Fat (olive oil) = Soap + glycerin.

The fact that fats are composed of fatty acids and glycerin has already been mentioned in the digestion of fats. So reference has been made to this fact, which greatly simplified the presentation of the process of saponification as simply a combination between the alkali, and the fatty acid 'part' of fats to make soap, and the glycerin is set free.

In about twenty-five minutes, the heating was stopped, and the contents of the beaker were allowed to cool. So before the class-session came to an end, the children could see that, after cooling, the chemicals in the beaker started to separate into layers of oil at the top, solid soap in the middle, and glycerin and alkali at the bottom. Common salt was added to quicken this separation of the layers.

The solid soap was then taken out, washed, and examined by the students.
b. The large scale production of soap.

I. The verbal groups:

After a short introduction, the members of the control verbal groups studied the diagram of the commercial production of soap exposed in figure 20 by a purely verbal method. The process of saponification in this modern soap pan is discussed in detail, showing the similarities and differences between the laboratory preparation and this large scale production of soap.

The processes of adding perfumes or colour, of converting the molten neat soap into frames, flakes or powder, and that of regaining glycerin and salt from the lye by evaporation were discussed only in broad terms.

2. The visual groups:

It was first planned to take the experimental groups in a field-trip to see a real soap kettle at work. This idea was however discarded because the experimental groups would have taken much more time than the control groups and the topic would have been treated in a much more detailed form. Other difficulties concerning the transport of all the members of the experimental groups at different intervals, securing the agreement of the soap factory and the school authorities, and the possibility that some of the students living at a distance from the college may absent themselves, were all anticipated.

Accordingly, a set of photographs, some of which are shown in
Fig. 21: Some of the still pictures presented to the visual groups.
figure 21 illustrating the different stages of large scale production of soap were used instead. They were shown simultaneously with the diagram.

It seems from what the experimenter could gather from the student's reactions, these still pictures were of great help to children, specially in describing processes for which the diagram did not cover in details, or has treated in an abstract way.

In this chapter explanations have been given of how the five experimental topics were presented in the light of the plans of experimental designs stated in the last chapter. The next chapter is intended to show what sorts of tests were devised to bring out any differences in abstraction, between the experimental and control groups, that are expected to be developed by the use of the audio visual and verbal methods described in this chapter.
(1) What kinds of abilities are to be measured?

As has been explained in previous sections, this study seeks to bring out differences in abstraction between the verbal and the audio visual methods of teaching general science by the help of the diagram. So, unlike the bulk of researches done in audio visual instruction, it is not the quantity of information learnt, nor the relative abilities of memorizing this information which this study wishes to measure, but rather the quality of learning that these methods of teaching have fostered.

It is much easier to construct tests that measure the knowledge of subjects about special topics or how much they can remember from them, but it is much more difficult to test for the 'type' of learning that they have acquired. This simplicity of the former kind of testing may be one of the main reasons for the tradition of over-verbalization that still persists even in countries where modern teaching materials have started to gain momentum in production and in class utilization.

As has been stated in chapter I, abstraction, concept-building and generalization can be described as a process by which an organism develops a symbolic understanding from a number of concrete experiences to which he is subjected, and that this journey from the concrete to
the abstract, passes through the antithetical processes of differentiation and integration. Hence, as the learner proceeds in the process of conceptualization, and starts to grasp the detailed characteristics of a certain situation, he will discriminate or differentiate certain relations that do not seem to fit any longer under the previous classifications of general concepts, and he will assimilate or integrate other items into larger wholes after discovering their relations with previously formed generalizations.

Accordingly all abstraction depends upon the cognition of relations. Higher order abstractions involve whole networks of such relations; but the beginning of the process of abstraction is the recognition of a relation in a factual statement; of identifying similar factual relations and distinguishing dissimilar ones.

It is clear that higher order abstractions are beyond the scope of this study. So the abstraction test constructed will deal only with first order conceptualizations.

(ii) The main abstraction test.

Since it was neither a test of knowledge nor memory as such, but that of preliminary abstractions, all the facts were given in the main abstraction test of this research. What was tested was the relative ability of the experimental and control groups to handle facts in an abstract form by identifying similar relations and recognizing dissimilar ones; that is to test their comparative preliminary capabilities of differentiation and integration in conceptualization.
Hence, the facts given in the test need not all be facts learned in the lessons, so long as they are the same type of fact. Thus, if on the whole, one method of teaching has promoted more abstract thinking than the other, this difference should show in the test scores, in spite of the minor weaknesses in the experimental design discussed in chapter II.

Educational literature on the construction of abstraction tests is very sparse indeed. Hence great difficulties were encountered in finding an adequate system of relations whereby this test could be made.

The findings of Prof. Meredith, in developing his new educational theory of relations, based on his technique of "topic analysis" and other studies in epistemics, is probably the most reliable work in this field. Accordingly, a simplified version of his system of relations was adapted in the construction of the novel abstraction test used in this study.

The scientific knowledge furnished by the topics was classified into sixteen distinct types of relations, which are all simple, fairly obvious relations which occur frequently in elementary scientific contexts. Each of these sixteen types of relations can be expressed in various forms. The difficulty of the questions constructed can be varied by putting the same relation in differing verbal forms and differing contexts. Thus the nature of relation was made to look obscure or obvious according to the verbal disguises or clues.

The system of relations utilized consists of four main types, namely, physical, biological, technical and logical. Each one of these four principle segments is subdivided into four relations, thus bringing the total to sixteen. A list of these sixteen relations is given below. Following it is another list of examples, one example for each relation of the first twelve types, and two examples for the last four (logical) relations, since these are more complex:

**List of Relations.**

I. **Physical Relations.**

1. Causal relations  
2. Spatial relations  
3. Temporal relations  
4. Constitutive relations.

II. **Biological Relations.**

1. Genetic relations  
2. Nutritive relations  
3. Territorial relations  
4. Protective relations

III. **Technical Relations.**

1. Manipulative relations  
2. Formative relations  
3. Permissive relations  
4. Transportive relations
IV. Logical Relations

1. Relation of type and meaning
2. Relation of class and number
3. Relation of deduction and consequence
4. Relation of truth and probability

A List of Typical Sentences.

I. Physical Relations

1. Causal
   
   eg. Enzymes change complex food into similar compounds.

2. Spatial
   
   eg. The penumbra surrounds the umbra.

3. Temporal
   
   eg. Glycerine is purified after being separated from the vapour.

   
   eg. Blood is made up of corpuscles and plasma.

II. Biological Relations

1. Genetic
   
   eg. Haemophilia has been an inherited blood disease of one of the Royal Families of Europe.

2. Nutritive
   
   eg. All animals live directly or indirectly on plants.

3. Territorial
   
   eg. Aquatic animals live in water.

4. Protective
   
   eg. Vitamins and mineral salts protect the body against disease.
III. Technical Relations

1. Manipulative
   eg. Salt slurry is separated in a centrifuge.

2. Formative
   eg. An umbra can be formed from a point source of light and an obstacle.

3. Permissive
   eg. The curd is allowed to float to the top of the mixture.

4. Transportive
   eg. The lye is drained off through the tap.

IV. Logical Relations

1. Type and meaning
   eg. (i) Caustic is a type of alkali.
       (ii) A fish is a kind of aquatic animal.

2. Class and Number
   eg. (i) Condensation and evaporation are opposite types of processes.
       (ii) The red corpuscles in the blood are more numerous than the white.

3. Deduction and consequence
   eg. (i) Air contains oxygen, therefore breathing purifies the blood.
       (ii) Fat is a compound and hence it must be split up to make soap.

4. Truth and probability
   eg. (i) In a lever of the third order the effort is always greater than the load.
       (ii) A man will probably become ill if he has too little oxygen.
To construct the test it was necessary to make 126 sentences similar in type to these given. Though the whole range of the topics taught were fairly equally distributed in these sentences, this was not adhered to precisely. In some cases even a few sentences from outside the topics were used.

Similarly, the use of the sixteen relations was not equally distributed among the sentences. It was found that the concepts conveyed by the five experimental topics, seem to depend more upon certain relations than others. For example, relations like causal, deductive and consequent, transportive, protective and spatial, seem to be used much more in the teaching of the topics than genetic, permissive and truth and probability relations. Accordingly an effort was made to make the frequency of use of a certain relation in the test sentences, roughly correspond with its frequency of utilization as a tool of conceptualization in comprehending the experimental topics taught.

The sentences constructed were arranged in groups of six, each group containing three pairs, each pair based on a single relation. The relation was not, as rule, extracted from the same topic, or expressed in the same or very similar verbal forms in both sentences, since this would have made the answers too obvious, though, a few of these easy ones were given at the beginning to give confidence.

So the 126 sentences constructed made 63 pairs. In groups of three this made twenty-one questions. The three pairs of sentences
constituting each question were arranged alphabetically, and children were asked to re-arrange them according to the three different types of relations used in the question. Arabic numerals were used to designate the questions, and letters to stand for the six sentences of each question. Students were asked to put their answers in a separate answer sheet a copy of which is shown with the test questions in Appendix "A".

Though the introduction to the test, prepared in a very simple language, presented two different solved examples including four sentences, (see Appendix) many students showed some signs of frustration when they found themselves faced with a new type of test which does not solve long essay writing. Hence the experimenter spent some time trying to explain what was required, using at times some Arabic expressions to make sure that everyone clearly comprehended what he was supposed to do. This frustration, however, quickly disappeared when they started to answer the test, and many of them said later on that they had really enjoyed answering this type of test which, according to them, had presented a real challenge to their "mentalities".

(iii) Scoring of the main abstraction test.

In most of the researches done in education and psychology, that involves testing, the test is either used as an instrument for measuring the aptitudes of the children, or the children as a tool for measuring the reliability or validity of the test. Neither of
these systems is employed in this study. What is to be measured is the relative efficiency of two methods of teaching. The comparative influences on the subjects, as measured by the abstraction tests, are considered the measure of the efficiency of the teaching methods. Accordingly, the students and the test make a combined instrument for measuring the efficiency of the method.

Since this study does not intend to measure individual children, individual child-scores are not needed. What is to be measured is their grasp of individual topic-relations. Accordingly, what is needed is the relation-scores; that is, the number of children who correctly answer each question. This is expected to show the test results as a distribution of relation-scores, thus showing the comparative efficiencies of the two methods in facilitating for the abstraction of special relations.

(iv) Perceptual abstraction test:

Other than the main abstraction test described above, two more 'drawing' test questions have been constructed to test the relative perceptual abstractions fostered by the two teaching methods in two different situations.

The aim of the first question is to test the validity of conventional science examination in measuring perceptual abstractions from the scientific diagram, and to see whether the value of audio visual materials as an aid to conceptualization from the diagram
1. Complete the following two diagrams of the digestive system of man.

2. Draw a diagram showing a white blood cell eating germs.

Fig. 22: The perceptual abstraction test.
can be measured by such conventional tests.

To do this, children were asked to complete the two diagrams of a human figure, shown in figure 22, by drawing his digestive system in both cases. As is evident, the drawing on the right, in which the human figure is directly facing the reader, is the simpler one which all the children have studied in the topic of digestion, and which is the one they are generally asked to reproduce in general science examinations.

On the other hand, the answer to the one on the left is supposed to be a profile of the digestive system drawn in the previous one. Hence those students who have developed proper perceptual abstractions from the two dimensional, cross-sectional diagram of digestion, they studied in the topic "Food and digestion", are expected to show this difference by imagining the whole, solid digestive system looked at from the side. Those who have not developed such conceptualizations, are not expected to be able to face this non-conventional test question, even though they may be able to answer the first 'traditional' part of the question.

This sub-test does not intend to measure the accuracy of reproducing the diagram of digestion from memory, it merely seeks to measure the ability of the child to see the concrete aspects behind the two-dimensional cross-sectional science diagram and to see whether conventional tests are capable of bringing out this aspect. So, one mark has been given for every student who produced
any appreciably reasonable diagram in the first place, and another mark if he could reproduce this diagram in the form of a "profile". Care has been taken not to let the artistic disability of the child to bias fair scoring; hence any acceptable diagram has been taken into consideration.

So the total number of the first category of marks stands for the number of children who proved to be capable of producing a reasonable diagram of digestion, and the second category for the number of those who could represent these diagrams in the form of a profile. It was found that to make the results of this question of significance, the total number of all the visual groups have been compared with the relative achievement of all the subjects in the control groups.

The other 'drawing' question was an effort to test for the real value of the 'cartoon' or the 'comic drawing' technique in helping abstraction from diagrammatic forms in general science teaching. As it has been mentioned in chapter III, the slide set of animated cartoons about the functions of the blood, had conclusively produced the most interesting class-sessions to the experimental groups.

To see whether proper abstractions have been developed, with the continuous joy and laughter at seeing blood carrying waste products of 'dust-bins' and guarding the body against disease by the help of 'machine guns', a simple drawing question has been given
to all groups. Children were asked to draw a white blood cell eating germs. As has been mentioned in Chapter III, visual and control groups were simply told that white blood cells fight bacteria by eating them up. Nothing about what bacteria looks like or how it is eaten up by white cells has been explained to any subjects, but the experimental groups saw a cartoon of a white blood cell eating bacteria out of a plate by the help of a fork and knife!

The kinds of drawings that the children would produce are expected to throw some light on the kind of perceptual abstractions that they have formed from the verbal or 'cartoon' approach in teaching the diagrammatic chart about blood shown in figure 7.

No grading system was followed in this question. It was felt that a simple verbal description may be more feasible.

Before closing this chapter, it must be re-stated that this two-question perceptual test constitutes only a minor part of the measurement techniques used in this study, and that it has been thought of only after the main abstraction test has been constructed, otherwise it might have been expanded and differently presented. However, even with its limited capacity, it proved to be very rewarding.

This chapter has presented a description of the different types of abstraction tests followed and the methods of scoring and measurements utilized. The next chapter is intended to give a summary of the results that these measurement techniques have given.
CHAPTER V.

A STATEMENT OF THE RESULTS.

I. Results of the main abstraction test.

(i) A general statement about the results of the main abstraction test.

For the sake of this discussion, the letter "V" will be used to stand for all the visual experimental groups, the letter "O" for the oral control groups, the letter "B" for the bright groups, "D" for the dull groups, the number "2" for the groups containing older children, and the number "1" to represent the groups made up of younger children. Hence the eight groups of which four were experimental visual of bright older, dull older, bright younger, and dull younger subjects, and the other four control oral groups will be referred to hereafter as VE2, VB2, VD2, VB1, VD1, for the experimental groups, OB2, OD2, OBL and OD1 for the control groups, respectively. Thus, VB2, will be compared with OB2, VB2, with OD2, VBL versus OBL, and VD1 against OD1. As it has been mentioned earlier, each one of these groups is made up of eighteen subjects.

A detailed account of the raw relation-scores of the 21 questions forming the main abstraction test is included in Appendix "B". As has been stated in the last chapter, each one of these 21 questions is made up of three pairs of sentences, representing three different types of relations which are to be re-arranged by the students. So the test has a total number of 63 pairs or 126 sentences.
The raw scores, accordingly, show the results of all these 63 relations. These raw scores stand for the number of subjects in any group who have correctly paired any of these 126 sentences. Since the total number of subjects in any group is 18, then, 18 is the total score, or full mark that any pair of sentences can attain.

The sixty three pairs of sentences are presented in the Appendix according to the relations to which they belong, so that the achievement of the various groups in any of the sixteen distinct relations used in the test, can easily be compared. The numbers of the questions and the sentences are sighted in a special column, for easy reference to the actual sentences of the test given in Appendix "A".

According to these raw scores, the grand totals of the eight groups in all the 63 pairs of sentences, and the differences between the experimental and control groups may be presented as follows, starting from the smaller to the larger differences between V and O groups:

<table>
<thead>
<tr>
<th>Group</th>
<th>Total</th>
<th>Total</th>
<th>Difference</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD1</td>
<td>503</td>
<td>533</td>
<td>-</td>
<td>503 = + 30</td>
</tr>
<tr>
<td>OD2</td>
<td>627</td>
<td>694</td>
<td>-</td>
<td>627 = + 67</td>
</tr>
<tr>
<td>OB1</td>
<td>536</td>
<td>685</td>
<td>-</td>
<td>536 = + 149</td>
</tr>
<tr>
<td>OB2</td>
<td>699</td>
<td>905</td>
<td>-</td>
<td>905 = + 206</td>
</tr>
</tbody>
</table>

A bird's eye-view of these results suggest that the use of audio visual aids has had a positive effect in facilitating
abstraction, since, at least, all the differences between the experimental and control groups are positive; but to see their significance, the mean scores of the eight groups according to their relative achievements in only one pair of sentences should be calculated. This may easily be done by finding the arithmatical mean (\(M\)) by the common formula

\[
M = \frac{\sum X}{N},
\]

where \(X\) is the grand total of the group in all the pairs of sentences, and \(N\) the number of these pairs (63).

These mean scores and differences between \(V\) and \(O\) groups, arranged in the same way as the grand totals and differences presented above, are as follows:

<table>
<thead>
<tr>
<th></th>
<th>VDI</th>
<th>VDI - ODI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODI</td>
<td>8.46</td>
<td>8.46 - 7.98 = 0.48</td>
</tr>
<tr>
<td>OD2</td>
<td>11.02</td>
<td>11.02 - 9.10 = 1.92</td>
</tr>
<tr>
<td>OB1</td>
<td>10.87</td>
<td>10.87 - 8.51 = 2.36</td>
</tr>
<tr>
<td>OB2</td>
<td>14.37</td>
<td>14.37 - 11.10 = 3.27</td>
</tr>
</tbody>
</table>

Even though the difference between the experimental and the control groups may not be very large when they are all taken together, comparing the differences between brighter, duller, older and younger \(V\) and \(O\) groups will give much more marked differences. These
Fig. 23: Graph showing the mean scores of the eight experimental and control groups.
differences are graphically shown in figure 23. Also the item
distribution charts presented in figures 26 and 27, will illustrate
this assumption in a more detailed method.

In spite of the fact that these mean scores have been very much
condensed by being averaged to a single pair of sentences, nevertheless
it is quite clear that brighter groups have benefited much more from
the use of audio visual materials than duller groups. As is shown
in the mean scores above and the graph in figure 23, VB2 - OB2 is nearly
twice as much as VD2 - OD2, and VBl - OBl is about five times as much
as VDl - ODl.

This fact may be illustrated more clearly by adding the differ­
ences between V and 0 bright groups and comparing this with the
corresponding differences between duller V and 0 groups; that is:

\[(VBl - OBl) + (VB2 - OB2)\]
as compared with
\[(VDl - ODl) + (VD2 - OD2)\].

Numerically, it will be as follows:

\[\frac{2.36}{3.27}\text{ as compared with }\frac{0.48}{1.92}\]
Difference \[= \frac{5.63}{2.40} = 3.23\]

This makes the net average gain of the brighter groups more than twice
as much as that of the duller groups in the pairing of any two sentences
out of the 126 sentences of the test.

It will also be instructive to examine the effect of age.

Although the element of age does not equal the effect of intelligence,
the mean scores show that it seems to have a similar positive influence in abstraction. The differences between experimental and verbal older groups are more than the differences between similar groups containing younger children. For example, while in the older brighter groups VB2 and OB2 the mean difference between them is $3.27$, the corresponding difference between the brighter younger groups is $2.36$. The average difference between the older dull V and O groups is $1.92$, while the younger dull groups present a difference of only $0.42$.

In following the same method utilized in comparing the total average net gain of brighter versus duller groups cited above, the positive effect of age in abstraction by the help of visual aids can be symbolically and numerically presented as follows:

$$\frac{(VB2 - OB2) + (VD2 - OD2)}{(VB1 - OB1) + (VD1 - OD1)}$$

Numerically:

$$\frac{(3.27) + (1.92)}{(2.36) + (0.43)} = \frac{5.19}{2.79} = 2.34$$

Difference = $5.19 - 2.84 = 2.35$.

Thus, though this difference between these two categories of averages is not as great as that caused by the aspect of intelligence, its significance becomes evident when it is compared with the whole range of differences between the V and O groups, and when it is recalled how condensed these averages are. The graph in figure 24
Fig. 24: The relative effect of intelligence and age in facilitating abstraction.
exhibits the effect of intelligence as compared with that of age.

The mean scores discussed in this section represent the average of all the sixty-three pairs of sentence-relations taken together. In reality, there has been much more differences between the scores of individual relations. As seen in Appendix "B", in some cases some of the control groups have even attained higher scores than corresponding experimental groups. The following section will deal with these results in more details.

(ii) A statement of the results of the four main divisions of relations.

It has already been stated in Chapter IV that the sixteen types of relations used in the main abstraction test of this study, are in fact sub-divisions of four main groups of relations, namely physical, biological, technical and logical relations. Each one of these groups is sub-divided into four distinct relations, thus making the total sixteen.

Before discussing the results of these sixteen relations individually, it may be more advantageous to discuss them under these general headings first. This will show whether there are any differences between these main divisions of relations as far as visual aids to abstraction are concerned. To make this general comparison more significant, the results of all V groups will be compared with the results of all O groups.

Since the frequency of use of different relations in the test have not been equal, the total average scores of each one of the 16 relations have been calculated from the raw scores shown in Appendix "B".
These mean relation-scores are presented in Table II. From these mean relation-scores, the total averages of the four divisions or groups of relations have been computed. Table I and figure 25 show all V groups compared with all O groups in these mean 'division-scores'.

From this table and graph, it is quite evident that the use of audio visual materials has improved abstraction most in technical relations, followed by physical relations, then logical relations and finally biological relations. It is interesting to notice that this arrangement is also true of the relative achievement of all the groups in these four divisions of relations. That is, both the experimental and control groups have achieved best scores in technical relations, followed by physical relations, logical relations and least scores in biological relations.

(iii) A statement of the results of individual relations.

To give a statement of the relative results of the various groups in the sixteen distinct relations, a more detailed approach will be followed. Table II shows the mean scores of every group in each one of these sixteen relations. As it has been mentioned in the previous section, these mean scores have been calculated from the raw scores presented in Appendix "B".

These mean relation-scores stand for the average number of children in each group who have successfully responded to the pairing of the sentences represented by the different sixteen relations tabulated. The scores range between zero and 18, because the number of subjects in each group is 18.
**TABLE I.**

The relative achievement of all experimental versus all control groups in the main divisions of relations.

<table>
<thead>
<tr>
<th>Divisions of Relations</th>
<th>Exp. Groups</th>
<th>Control Groups</th>
<th>Exp.-Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Relations</td>
<td>50.02</td>
<td>42.14</td>
<td>+ 7.88</td>
</tr>
<tr>
<td>Physical</td>
<td>49.04</td>
<td>41.32</td>
<td>+ 7.72</td>
</tr>
<tr>
<td>Logical</td>
<td>43.24</td>
<td>37.32</td>
<td>+ 5.92</td>
</tr>
<tr>
<td>Biological</td>
<td>38.52</td>
<td>33.48</td>
<td>+ 5.04</td>
</tr>
</tbody>
</table>
Fig. 25: The relative achievement of all the experimental versus all the control groups in the main divisions of relations.
To show the significance of the differences between the four pairs of V and 0 groups, and to present the results in a meaningful visual form, the mean scores of each pair of experimental and control group will be expressed by Meredith's "item distribution method". By this technique, the twin mean relation-scores of each pair of V and 0 groups will be plotted in an "item distribution chart".

As seen from figures 26 and 27, this relation or item distribution chart is divided from zero to 18 vertical segments, to stand for the visual group, and from zero to 18 horizontal sub-divisions to represent the members of the corresponding verbal group. Thus the mean scores of the visual and verbal groups in a particular relation can be plotted in one point by using these two visual and oral co-ordinates.

If, for example, an average of 15 boys from the experimental group have given correct responses to a special relation as compared with 12 students from the control group, then these two mean scores will be plotted in a single point which is exactly opposite to the 15th vertical segment of the visual group, and exactly opposite to the 12th horizontal segment of the corresponding verbal group.

A diagonal drawn in the middle of the chart makes a dividing line between the two groups. Hence all the relations in which the visual group does better will be on the 'visual' side of the chart and vice versa. The distance of any particular relation-score from the dividing line will thus vary directly as its power of discrimination between the two groups.
After this description of the item distribution method, we start a general discussion of the relation distribution charts exhibited in figures 26 and 27. Table II which includes the mean relation-scores from which these charts have been made, also contains a list of the abbreviations of the sixteen relations used in their preparations. The abbreviation is put between two brackets opposite to the full wording of the corresponding relation in the table.

In preparing the charts, four colours have been used to stand for the four main divisions of group relations. Red represents the four physical relations, green the biological relations, blue the technical and black the logical relations. Chart No. 1 shows the mean scores of VB2 versus OB2, chart No. 2 presents VD2 against OD2, chart No. 3, VBl compared with OBl, and chart No. 4, VDl and ODL.

The general outlook of these four relation distribution charts verifies very clearly the general results of this main abstraction test discussed in section (i). By comparing charts No. 1 with chart No. 2, and chart No. 3 with chart No. 4, the positive effect of intelligence in aiding abstraction through the use of visual materials will be very evident. In charts 1 and 3, which show the differences between bright visual and verbal groups, the plotted relations are comparatively much more scattered, and nearly all on the visual side of the charts.

In charts No. 2 and No. 4, on the other hand, the differences between dull experimental and control groups looks comparatively much less. Plotted relations are either very near to the dividing line
<table>
<thead>
<tr>
<th>Time (min)</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>8.40</td>
<td>9.60</td>
<td>11.80</td>
<td>14.00</td>
<td>15.30</td>
<td>16.80</td>
</tr>
<tr>
<td>0.44</td>
<td>7.78</td>
<td>7.89</td>
<td>7.99</td>
<td>8.09</td>
<td>8.19</td>
<td>8.29</td>
</tr>
<tr>
<td>0.53</td>
<td>7.70</td>
<td>8.00</td>
<td>8.30</td>
<td>8.60</td>
<td>8.90</td>
<td>9.20</td>
</tr>
<tr>
<td>0.69</td>
<td>7.00</td>
<td>7.30</td>
<td>7.60</td>
<td>7.90</td>
<td>8.20</td>
<td>8.50</td>
</tr>
</tbody>
</table>

**Table II**

The mean scores of experimental and control groups on individual ratings.
or even on the side of the oral groups. While there are ten relations in which the oral groups have scored better averages than experimental groups in chart 2 and 4, there are only two similar relations in the case of charts 1 and 3.

The influence of age in facilitating abstraction through the help of audio visual materials, can also be shown by studying these four relation distribution charts. Comparing charts 1 and 2, which presents the differences between older bright and dull subjects with charts 3 and 4 which display corresponding differences between younger students will visually illustrate the positive effect of age already discussed in section (i).

Though the difference between the net gain of brighter and duller groups is greater, this comparison between older and younger subjects is also of significance. In chart No. 1, comparing VB2 with OB2, the sixteen relations, comparatively more spread out, are all on the visual side of the chart. In chart No. 3 collating brighter young children, two relations are well into the side of the verbal group of the chart, and a third relation is exactly on the dividing line.

In examining chart No. 2 exhibiting the comparative results of older dull students and chart No. 4 collating dull younger children, the difference is even greater. The general outlook of the two charts show this difference clearly. In the first case, the relations are more spread out towards the visual segment of the chart. Also, in the case of the older dull children the oral group have scored better
Fig. 26: Relation distribution charts of older children.
The results are that the visual one in four relations is the case of the experimental group. The visual one in four relations is the case of the experimental group. The visual one in four relations is the case of the experimental group.

Hence, the item distribution method have presented a further confirmation of the results this intelligence, and to a lesser extent age have a positive effect in paving the way for conceptualization through the use of audio-visual aids in science teaching.

A closer look at the item distribution charts will show that while the conceptual relations of such relations have been improved by the use of visual materials, the relative degree, of course, vary. In fact, some relations seem to be more tendency to the verbal suppression. The latter case is specially true of some biological and logical relations.

The spatial, genetic, and formative relations seem to be the ones which abstraction has been improved the greatest by the use of visual records. With the exception of chart No. 2, showing the verbal versus OBI, the genetic and formative relations stand out as one of the most discriminating relations in the other three cases. Though the formative relation is not so much discriminating in chart No. 1, it is very useful in the charts of the younger groups. The spatial relations is one of the most discriminating in all four charts.

Fig. 27: Relation distribution charts of younger children.
results than the visual one in four relations; in the case of younger dull children, the number of similar relations is six. In one of these six relations the net gain of the control group over the experimental group is very much greater than any of the four similar relations mentioned in connection with the older duller groups.

Hence, the item distribution method have presented a further confirmation of the results that intelligence, and to a lesser extent age have a positive effect in paving the way for conceptualization through the use of audio visual aids to science teaching.

A closer look at the four relation distribution charts will show that, while the conceptualization of most relations have been improved by the use of visual materials, in varying degrees, a few others have not. In fact, some relations seem to be more 'suited' to the verbal approach. The latter case is specially true of some biological and logical relations.

The spatial, genetic and formative relations seem to be the ones which abstraction has been improved the greatest by the use of audio visual forms. With the exception of chart No. 2, showing VD2 versus CD2, the genetic and formative relations stand out as two of the most discriminating relations in the other three cases. Though the formative relation is not so much discriminating in chart No. 1, it is very much so in the charts of the younger groups. The spatial relation is one of the most differentiating in all four charts.
In the field of logical relations, deduction and consequence, which is nearly as discriminating as the spatial and genetic relations in the brighter older and younger groups, has not become so differentiating by the use of visual aids, in the case of duller groups. In fact, in the case of the older duller groups, it is nearly situated on the border line. Similarly, the relation of type and meaning, though fairly well into the 'visual zone' of the brighter older and younger groups, is not a very discriminating relation as far as the duller groups are concerned.

The technical transportive relation presents a similar situation; although fairly differentiating with brighter groups, has been advanced by the use of verbal methods in the case of duller groups.

The other two logical relations of class and number and truth and probability, produce an interesting case. The former one, though very near to the dividing line, but still in the visual side of the older bright groups, and well into the verbal section of the younger brighter group, which means that its conceptualization has been very much improved by verbal methods, its abstraction seems to be fairly improved by the use of audio visual aids in the case of the duller two groups! The latter one, truth and probability, seems to be more suited to verbal methods. It is not a discriminating relation in the brighter groups, and is right into the verbal sections of the duller two groups.

Other than the genetic relation which, as already stated, greatly favours the use of audio visual aids to abstraction, the rest
of the three biological relations certainly do not follow the same line. The abstraction of the three of them have either been improved by verbal methods or they have been very near to the border line, but in the visual 'zone'. For example, the use of the verbal approach has advanced the conceptualization of the nutritive relation in three distribution charts, and is near the dividing line of the visual segment of the fourth, older brighter group. Similarly, the protective relation, though in the visual section, is very near to the border line of the two older bright and dull pairs of groups, and the brighter younger groups. In the case of the fourth pair, its abstraction has been improved by verbal methods. Though the territorial relation has been a discriminating item in the case of the younger bright groups, it has not been so with the older bright groups and the duller younger groups. In the case of the duller older groups, its abstraction has been bettered by verbal methods.

Accordingly, it can be concluded that the results of individual relations show that the spatial, the genetic, and the formative relations greatly favour the use of visual methods, that the abstraction of deduction and consequence, type and meaning, and to lesser extent the transportive relation, have been greatly improved by visual aids in the case of brighter but not duller groups, that the conceptualization of class and number has been advanced by the use of visual materials in the case of duller but not in brighter groups, and that the nutritive, the territorial, the protective, and the truth and probability relations seem to favour the use of verbal methods.
The other relations though mostly on the visual side, have not been very much affected by the use of audio visual methods and materials.

II. Results of perceptual abstraction test.

The findings of the perceptual drawing test have been very interesting. The results of the first question about the completion of the two human figures by drawing their digestive systems in the conventional form, and in a profile of the conventional form, has been as already mentioned, calculated for all V groups against all O groups. For the first part of drawing the digestive system while the human figure was looking straight at the students, the conventional way, a total of 57 students from all the control oral groups, and a total of 55 from all the visual groups, produced diagrams that were reasonably acceptable.

Out of the 57 students of the O groups, only 18 managed to produce acceptable profiles of the digestive system they have drawn in the first instance. A good many of them have simply reproduced the first diagram of digestion in the second outline of the human profile. A few of them did not attempt to answer this second part at all though they have drawn comparatively good conventional diagrams.

Thirty-nine subjects out of the 55 students of the visual groups, on the other hand, have managed to draw acceptable profiles of the conventional diagram of digestion. Some of them have produced very good cross-sections by showing where the large and small intestines were 'crossed', and shading those areas. A few of them have even
used numbers or letters to signify the position of various digestive organs in the profile, in respect to the first conventional drawing of the digestive system. By giving one mark for each part of this question, the scores are shown in Table III.

### TABLE III

The results of the first question of the Perceptual abstraction test.

<table>
<thead>
<tr>
<th>Type of Diagram</th>
<th>V groups</th>
<th>O groups</th>
<th>V groups - O groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional diagram</td>
<td>55</td>
<td>57</td>
<td>-2</td>
</tr>
<tr>
<td>Profile</td>
<td>39</td>
<td>18</td>
<td>+21</td>
</tr>
</tbody>
</table>

The results of the second question have been disappointing for the experimental groups, since a good many of them have shown that the animated drawing set of 'cartoon' slides about the functions of the blood have not helped them in developing mature concepts about how white blood cells really fight germs, how they 'eat them', or how bacteria looks like.

Whether it is because they could not think of any other visual perception of a white blood cell eating bacteria, or whether they really believed that what they were drawing was not very different
different from reality, some boys from the visual groups have tried to reproduce the cartoon of the white blood cell eating bacteria by the help of a fork and knife, which they saw in the film slide presentation! While some of them have given their drawings a local Sudanese atmosphere of eating a meal without a fork and knife, two other subjects have even introduced a table and a chair into the scene. Most of these children however were from the dull and younger groups.

In most of the other cases in which this cartoon slide have not had such a direct influence, the ratio of the size of the white blood cell to that of the bacteria, and the shape of the bacteria have been greatly distorted by its indirect effect.

On the other hand, the drawings of the verbal groups, though in many cases far from reality, generally show more balanced concepts of this phenomenon. The drawings made by various groups were so varied that it was felt that giving such broad generalizations about them, may be more natural and more informing than any system of scoring.

As it has already been stated in the last chapter, this perceptual drawing test is simply a minor branch of the main measurement techniques of relations discussed in previous sections of this chapter; however, its results, are hoped, will be of help in interpreting the findings of the main test and in formulating the conclusions of this study, which will be discussed in the next chapter.
CHAPTER VI.

Interpretation and discussion of the results.

The main aim of this research study was to compare two approaches to abstraction, or concept formation; the one by a verbal approach to diagrammatic forms used in the teaching of general science, the other by an audio visual approach to the same diagrams. Five general science topics, "Food and digestion", "Blood", "Shadows and eclipses", "Levers", and "Soap making", were taught to a total sample of 144 Sudanese secondary school subjects. This sample was divided into eight groups of bright older, dull older, bright younger, and dull younger, audio visually taught experimental, and carefully matched verbally taught control groups of eighteen subjects in each group. The measurement techniques, described in Chapter IV, consisted of a main abstraction test of identifying similar relations and distinguishing dissimilar ones, by re-arranging 126 sentences into 63 pairs of sixteen distinct relations. The other part was a perceptual abstraction test, measuring the relative accuracy of the perceptual concepts formed by experimental and control groups concerning the diagram of human digestion and the way in which white blood cells fight bacteria.

The general nature of the results of these abstraction tests, described in Chapter V, shows that the use of audio visual materials has had a positive effect in facilitating the abstraction of scientific knowledge conveyed through diagrammatic forms. This statement of the
results agrees with the general trend of the very few similar researches treating this subject from the audio visual or the psychological points of view. The findings of Heidbreder,\(^1\), Carson\(^2\), Vergis\(^3\), and Rulon\(^4\), described in Chapter I, are examples of such studies. This research, like the ones quoted above, disproves the frequent unfounded criticism that audio visual materials, though effective in helping children in acquiring information, have a passive or even a negative role in concept building.

Considering the diagram as an audio visual aid, this study can be viewed as an experimental comparison in abstraction, between the teaching of general science through the use of one visual aid, the diagram, with teaching it through the use of more than one visual aid, the diagram plus more concrete audio visual materials. From this point of view, the general statement of the results, proving that the use of more concrete audio visual materials with the diagram has improved abstraction, can be considered as a confirmation, in the field of conceptualization from the diagram, of the findings of a number of experiments performed to test the efficiency of one visual material against the use of more than one material in acquiring factual information or in retention\(^5\).

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2. D. Carson, *op. cit.*
3. J.P. Vergis, *op. cit.*
Another conclusion that can be extracted from this general statement of the results, is that, since visual materials advanced the degree of abstraction from the science diagram, then such diagrams must have been highly abstract without the help of these concrete materials. As has been stated in Chapter I, the diagram is a visual symbol of the real thing; in general science, it is made to look more abstract since it does not generally represent the real thing as such, but the cross-section of the real thing or some other highly symbolic form of it. In some cases, it even stands for concepts such as sound and light waves and magnetic lines of force, which are too abstract to be seen by the human eye. This conclusion also agrees with M.D. Vernon's\textsuperscript{1} summary of researches done in Britain about the diagrammatic and graphic forms, which is cited in Chapter I.

The fact that the use of visual materials has succeeded in aiding abstraction from the twelve diagrams used in this research also verifies the findings of the pilot research done in Lansdowne Secondary School about the most suitable method of presenting the visual aids with the diagrams. As explained in Chapter II, in this pilot experiment, five different methods of presenting the visual materials with the diagram were compared while the teaching of the topics was tried out in the above mentioned school. These five presentations of the visual materials were, before the diagram,

\textsuperscript{1} M.D. Vernon, \textit{op.cit.} p. 147-58
simultaneously with the diagram, after the diagram, before and after the diagram, and the diagram itself presented before and after the visual aid.

The general conclusion of this pilot experiment was that, on the whole, children need much more explanation than had been expected to see the intricate connections between the diagram and visual aids explaining it, and that they often see the visual aid as an interesting way of a change from conventional teaching, and the diagram as something 'solid' to study separately for tests, and so fail to see all the relations between them. This conclusion was inferred from the fact that those who saw the diagram before the visual aid and after it, those who saw them simultaneously, and those who saw the visual aid before the diagram and after it, did better in the oral testing than those who saw the diagram only before or only after the visual materials, since they failed to see all the connections between them. The findings of this pilot research have decided the methods of presenting the visual material with the diagrams in teaching the actual experimental topics in the Sudan. Hence, the success of the experimental groups in achieving better scores in the abstraction tests may be taken as an indication that the findings of the pilot research were of significance.

Although a generally held view is that audio visual methods are most suitable with dull and young learners, and that they are not as helpful to brighter and older children, who can even do without
them, the results of this research study decisively proves the opposite, a statement which probably indicates the most important contribution made by this experiment. The view that audio visual materials can help duller and younger children more than brighter and older ones, is probably a generalization extracted from a number of audio visual researches dealing with the acquiring and retention of factual knowledge. In such cases, the impression that younger and duller children gain more from visual aids may be attributed to the fact that their general capacity for comprehension, insightful learning, span of attention and hence their 'patience' with conventional, purely verbal methods is much less than that of older and more intelligent children. Thus the use of audio visual materials, with all its concrete, interesting and motivating qualities, may be of more help to these younger and duller learners than older and brighter ones who do not encounter similar difficulties in learning factual knowledge.

The dearth of research in the audio visual and educational psychological studies investigating the value of the visual element in abstraction may be the reason for this one-sided view of associating visual materials with dull and young children. This is a point of view which has been embraced by some of those who do not favour the use of audio visual materials in order to limit their utilization.

Acquiring or retaining information is one thing and conceptualization is quite another. In the first case a student may accumulate
a huge amount of 'inert' factual knowledge about a certain topic or simply try to memorize what he has already aggregated; in the second case, a more complicated process of developing a symbolic understanding from this great mass of concrete and semi-concrete information, by following the antithetical processes of differentiation and integration, already discussed in detail in Chapter IV is pursued. By borrowing an illustration from the digestive system, the first case of acquiring various kinds of factual knowledge may be represented by the simple process of ingesting different types of food-stuffs. The process of conceptualization, on the other hand, is similar to that of the actual digestion and assimilation of food. Changing these crude food-stuffs by the action of juices into much simpler and soluble compounds may stand for the process of differentiation or discrimination. The absorption of these soluble compounds to form different types of tissue cells, to undergo further synthesis, or to form stored fats and glycogen can represent the process of integration, of collecting various forms of differentiated items to form new wholes and generalizations. Hence to follow the process of abstraction properly, intelligence and maturity will be of much greater help than in the case of the simple 'ingestion' of facts. So, the more intelligent a child is, the more will he be able to deal with abstractions, and the more will he be able to make use of audio visual materials to improve these abstractions. As he grows older, his mental capacity and his scholastic experiences will also develop. This will give him a better chance of using these
materials for aiding conceptualization. This conclusion, is hoped will help in giving a more balanced view of the role that audio visual instruction can play in all fields of child and adult education.

Although the results of this study show that the element of intelligence has given elementary abstractions from the science diagrams a slightly greater impetus than that of age, it must be remembered that, as stated in Chapter II, the second and third year classes were found to be the only suitable age-groups for the research, and accordingly the difference in age between the older and younger groups have been comparatively smaller than that of intelligence. So, in spite of the fact that the mental ability of a child continues to develop till he reaches the age of twenty or even beyond\(^1\), the positive influence of age in conceptualization, may be attributed to the increase in intellectual experiences more than to mental growth. Had the difference between younger and older groups been more, the influence of age might have been as great as that of intelligence, but as conditions stand now, a safe generalization would be that, intelligence, and to lesser extent, age have a marked positive effect in facilitating for abstraction from the science diagram, through the help of audio visual materials.

As for the results of the four divisions or groups or relations, comparatively larger differences between all visual and verbal groups in the technical and physical relations, and the comparatively smaller

\(^1\) F.N. Freeman and C.D. Flory, op.cit.
differences in logical relations, can be explained by the fact that technical and physical relations made up from sub-divisions like spatial, causal, constitutive, manipulative, formative and transportive are more adapted to the practical nature of audio visual instruction than logical relations. Also many of the former category of relations e.g. spatial, causal, transportive, have probably been used more in teaching the topics than some logical relations like class and number and truth and probability.

On the other hand, the comparatively very small difference that biological relations have attained, which presented an unexpected result, cannot be explained as easily. It is true that some of the biological sub-divisions of relations have not been so frequently used in the topic teaching, but still it was not expected that the differences between visual and control groups would come out to be smaller than that of logical relations. In fact, the biological genetic relation, which has been the least used in the teaching of the topics, have turned out to be one of the most discriminating relations in nearly all the eight groups, by being greatly improved by the use of visual forms. This may be partly explained in the case of one of the dullest visual groups where the dissected rabbit was found to be pregnant! However the comparatively low standard that all the visual groups have achieved in the perceptual abstraction question of "draw a white blood cell eating bacteria", may suggest that the misleading concepts presented by the cartoon film-slide
about the functions of the blood to be the reason for the fact that the results of the remaining three protective, territorial and nutritive biological relations have been in favour of verbal rather than visual methods.

The logical relations of type and meaning and deduction and consequence, the abstraction of which have been greatly improved by the use of visual aids in the case of brighter, older and younger children, but not in the case of duller subjects, may be due to the possibility that these two relations, probably more than all the other fourteen, represent the child's capabilities in the two antithetical processes of differentiation and integration, upon which the whole process of abstraction depends. To differentiate various items in a situation, the learner will need to see the different "types", and comprehend the various "meanings" conveyed by those items, and hence, the result of the relation of type and meaning may accurately stand for/child's ability of differentiation. The process of integration, on the contrary, involves the recognition of the relation between two or more facts that are seen together or that may come one after the other. The item of deduction and consequence, accordingly, which involves two different facts, having some kind of connection between them, and which come in some form of consequence, can be a good measure for the student's capability in this process. Brighter children, who have a greater capacity of conceptualization, are thus expected to make more use from the visual
teaching in developing their understanding of these two relations
and seeing the subtle points conveyed by the concrete materials,
which duller children may fail to perceive.

Conversely, the relation of class and number, the results of
which seem to favour the use of visual aids with duller groups, and
the verbal approach in the case of brighter groups, may be inter­
preted as one of those "abstract" logical relations the conceptual­
ization of which can be improved by a lengthy verbal discussion
rather than the use of many concrete aids with a comparatively less
utilization of words. To be able to make use of this verbal
approach, however, learners who have a greater capacity for con­
ceptualization, who can follow the intricate verbal discussions,
with more comprehension and concentration, and hence who have more
intelligence, can do much better than duller children who cannot
follow the verbal long discussions of such a logical relation with
the same interest, understanding and patience. To the latter group,
the use of visual aids may accordingly prove to be more advantageous.

The fourth logical relation of truth and probability, seem to
be even more suited to the verbal approach since almost all of the
verbal groups have achieved better scores than the corresponding
visual groups.

In the last few pages, an effort was made to discuss and
explain the results of individual relations. Obviously, more
detailed interpretations may not be essential, since more specific
generalizations may not be permissible. As explained in Chapter II, in spite of all the efforts made it would not have been possible to bring all the variables involved in this research under complete control. Also, this study, being one of the extremely sparse researches done in its line, and probably the first to use such a type of relation abstraction test, may be viewed as a pioneer pilot experiment in its field of study, its methods of research, and its measurement techniques. Thus, the lack of previous pertinent literature will have to limit the scope of further specific conclusions concerning the abstraction of individual relations.

As for the results of the first part of the perceptual abstraction test, in which 57 subjects from all the oral groups, and 55 students from all the visual groups produced acceptable conventional diagrams of human digestion, and out of the first category only 18 managed to draw profiles of the human digestive system, which was produced by 39 boys from the visual groups, the following interpretations can be extracted.

First, this result proves that the use of some traditional school general science tests, in which the child is asked to reproduce a special diagram from memory, may be a good measure for the child's ability to retain facts presented in the traditional wall charts, textbook or blackboard diagrammatic forms, but it may not be as efficient in telling whether the child has developed any sort of proper concepts or abstraction from what he is drawing. Though
the subjects who could draw good conventional diagrams from the verbal groups were slightly more numerous than corresponding children from visual groups, when it came to the real test of perceptual abstraction, the visual groups presented more than twice as many children.

Secondly, this result proves that subjects are capable of producing good labelled scientific diagrams without really having developed proper abstraction from what they are drawing. This conclusion may be considered as a perceptual manifestation of psychological studies proving that children who were really ignorant of many concepts used freely in their school textbooks, could use these concepts correctly in their oral conversation or written work. The study made by Pressy\(^1\), which is condensed in Chapter I is an example of such researches.

From the general trend of these results, in which slightly fewer of the audio visually taught students could draw conventional diagrams, but many more of them could draw proper profiles, a third interpretation may be that students who have acquired fairly good perceptual abstractions from a science diagram, may not be able to reproduce the conventional form of that diagram with a high degree of accuracy. This interpretation may also be considered as a visual manifestation of psychological researches in conceptualization carried by experimenters like Smoke\(^2\), Heidbreder\(^3\), and Hull\(^4\), quoted in Chapter I, who have shown that subjects might fail to give satisfactory

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1 L.C. Pressy, _op.cit._
2 Smoke, _op.cit._
3 Heidbreder, _op.cit._
4 Hall, _op.cit._
verbal definitions of special concepts though they were entirely capable of using them.

The results of the second question about drawing a white blood cell eating bacteria, simply draws attention to the danger of the use of the cartoons and 'comic drawing' techniques as a visual aid to abstraction in science teaching. The comparatively poorer perceptual concepts developed by the visual groups show that the use of such cartoons or 'comic figures', though most interesting to students and teacher, can be misleading to young learners. The concepts utilized by the artist, if not fully understood as simply "artistic tricks", can hinder the abstraction of scientific information rather than facilitate for it. The results of this question displayed that this phenomenon showed itself more clearly in the case of duller and younger children. Hence it may be concluded that for aiding abstraction from the science diagram or chart, a more concrete, life-like visual aid may generally be preferable. But if they are used, the science teacher should not spare any effort in explaining all the artistic symbols used in them, and he should not take the apparent interest and amusement exhibited by the children as a sign of proper understanding and conceptualization.

After this discussion of the results in which various interpretations and conclusions have been distilled in the light of previous research and psychological theory, a summary of these conclusions will conclude this dissertation.
Summary of conclusions

1. Most of the science diagrams presented to secondary school learners in the form of blackboard, wall chart or textbook drawings are highly abstract. In most cases, the use of concrete and semi-concrete audio visual aids can greatly improve the abstraction of the information conveyed by such diagrams.

2. Even when a concrete or semi-concrete audio visual aid is used to advance conceptualization from a scientific diagram or chart, every effort should be used to show the connection between the two. Science diagrammatic forms are generally cross-sections of reality, distorted, highly symbolic representations of it, or very abstract representations of concepts such as sound waves and lines of force that cannot be drawn on paper as they exist. This fact though apparently simple, is often overlooked by the young learner. More concrete audio visual materials on the other hand, are 3-D objects or solid and pictorial representations of these objects. Occasionally, children first see the visual aid as an interesting way of a change from traditional teaching, and then they study the diagram as a different item which they will be asked to reproduce in tests, thus failing to see the detailed connections between the two.

3. Hence to guard against this possibility, every effort should be devoted to show the relation between the diagrammatic form and the visual aid explaining it. Showing the diagram before and after the visual aid, presenting the visual aid before and after the diagram,
or showing them simultaneously, may be of greater help in aiding abstraction than a single unrevised separate presentations of these two categories of teaching tools.

4. Considering the diagram as a visual aid, it can be concluded that often the use of more than one visual material results in better abstraction than the use of one visual aid, since the disadvantages of one material can be overcome by the advantages of the other.

5. Unlike the generally held view that audio visual aids are a greater help to slow and younger children than brighter and older ones, a point of view that might have been derived from the bulk of research studies investigating the value of projected audio visual materials in acquiring or retaining factual information, as far as the process of abstraction from the science diagram is concerned, brighter and older children can obtain more benefit from audio visual instruction than dull and younger children. Though both aspects have a marked positive effect, intelligence seems to have a greater influence in facilitating abstraction.

6. On the contrary, as far as dull and younger students are concerned, visual materials can have no effect or may even hinder the degree of abstraction of certain relations, e.g. certain logical and biological relations. This may be due to the fact that young and dull students may fail to see some of the disguised and intricate connections between the diagrams and visual aids, which the brighter and older children, who are expected to have a greater capacity for dealing with abstractions, can observe.
7. It seems that, by and large, due to its practical nature, audio visual instruction can improve the abstraction of technical and physical relations more than biological and logical relations.

8. The conventional general science examinations do not generally show whether the learner has developed correct perceptual concepts from the diagrams and charts he has studied or not. Students of science, by the simple process of memorization, can produce very good labelled diagrams and charts without fully grasping the perceptual concepts behind the visual symbols they are drawing. On the contrary, it seems that children may develop fairly accurate concepts from scientific diagrammatic material without being able to reproduce its detailed form as supplied by conventional wall charts. As may be expected, audio visual materials are of tremendous help in furthering such perceptual conceptualizations.

9. The use of cartoons and "comic drawing" techniques as a visual aid to abstraction, though most interesting and amusing to students and teacher, can be misleading to young learners. The concepts utilized by the artist, if not fully understood by children as simply artistic techniques can hinder abstraction from science diagrams rather than facilitate for it. This is specially true of dull and younger children, and those who have not had enough experiences with the artistic symbols used in such drawings. If used, the teacher should accordingly be sure to explain these symbols very well; but to make concrete an abstract diagram, a more realistic visual aid
should generally be used instead.

10. This being the case, to improve conceptualization from an abstract visual aid, it should be coupled by a more concrete audio visual material. The use of a less concrete, or equally abstract audio visual form may do more harm than good in furthering abstraction.
Further Investigations

Before concluding this dissertation, it may be useful to discuss briefly some of the aspects of this research which may make further helpful contributions if followed up by more experimental work. As has been pointed out earlier, this experiment being one of the extremely sparse researches done in its line, and probably the first to use the relation abstraction test described in previous sections, may be viewed as a pioneer pilot research in its field and methods of research. Accordingly, to confirm the reliability of its conclusions, especially those that have not been strongly supported from the statistical point of view, the contributions of further experimental work may be of paramount importance. The weaknesses in the experimental design of this study that has been revealed in Chapter II, can be avoided in these experiments.

Such researches may be of great help in reaching more reliable and specific generalizations about the relative value of visual aids in improving the abstraction of the various divisions and subdivisions of relations, which this study, handicapped by the dearth of pertinent literature, could not reach specific conclusions about. In fact, the great potential usefulness of Meredith's educational theory of relations, cannot really yield its fruits unless it is thoroughly experimentally investigated.

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1 Prof. G. P. Meredith, _op.cit._
Although the topics taught in this research study included the three main branches of general science, physics, biology and chemistry, the limitations of time, the size of the sample, and the novelty of the measurement techniques, have made it difficult to probe into the connections between the sixteen types of relations used, the specific kinds of visual aids utilized, these three main branches of general science, and the relation of all these factors to the age and intelligence of subjects. These specific aspects may form a very interesting follow up to this study. Ideally, the contributions of such studies would allow the science teacher preparing for a special topic in a branch of general science to divide the lessons in the form of individual relations, and then choose the most suitable visual materials according to these types of relations and the age and intelligence of the children he is going to teach.

In spite of the fact that they have not been extracted from the main body of the research project of this study, the conclusions about the most suitable ways of presenting the visual aid with the diagram, so that concepts may evolve more easily, and the advantages and disadvantages of the use of the 'cartoon' as a visual aid to science teaching, may be of practical help to the science teacher if more direct researches are carried out to re-examine these conclusions experimentally.

It is hoped that this and similar studies, investigating the use of audio visual aids in the light of the findings of educational psychology, will help in formulating a more balanced outlook to audio
visual instruction, and hence showing the role it can play in child and adult education; a mature balanced outlook free from superficial enthusiasm for visual aids on the one hand, or unfounded biased prejudices against their use on the other.
APPENDIX A.

I. Main Abstraction Test.

II. Perceptual Abstraction Test.
I. Main Abstraction Test

Introduction to Test

Read the following two sentences carefully. They are both about different scientific facts. In each fact there is some kind of connection between two things. The facts are different but the connection is of the same kind in both facts.

(a) The moon can cause an eclipse of the sun.
(b) Oxygen can turn dark blood red.

In both these facts one thing causes another.

Now look at these two sentences:

(c) In the first-order lever the fulcrum is between the load and the effort.
(d) In an eclipse of the moon the earth is between the moon and the sun.

In both these facts one thing is between two others.

Now suppose these four sentences had been arranged differently, like this:

(a) Oxygen can turn dark blood red.
(b) In the first order lever the fulcrum is between the load and the effort.
(c) The moon can cause an eclipse of the sun.
(d) In an eclipse of the moon the earth is between the moon and the sun.

If you were asked to sort these four sentences out into two similar pairs would you be able to do it? The correct answer is:

(a) is like (c)
and (b) is like (d)

There are many other kinds of connections between facts. In
the following test each question has six sentences. You have to sort them out into three pairs, so that in each pair the connection is the same in both facts.

1. (A) Blood carries waste products of urea from the liver to the kidneys.
   (B) Carbon dioxide makes blood dark purple in colour.
   (C) Digestive juices change complex food into simpler compounds.
   (D) Food is transported from the mouth to the stomach through the oesophagus.
   (E) Soap is composed of a fatty acid and an alkali.
   (F) White cells, red cells and plasma make up blood.

2. (A) A black short man who marries a black short woman is expected to have black short children.
   (B) The camel is protected against starvation by its hump.
   (C) We feel healthy and strong when we eat good food, which shows that food contains energy.
   (D) Haemophilia, a disease which hinders blood from making a clot, has been an inherited disease of one of the royal families of Europe.
   (E) Light travels in straight lines so shadows exist.
   (F) White blood cells fight disease.

3. (A) An aquatic animal lives in water.
   (B) In a lever of the second type, a small effort always supports a larger load.
   (C) One of the simplest machines is the lever.
   (D) Palm trees are found in the desert.
   (E) Sodium hydroxide is a very useful alkali.
   (F) When the moon comes in a straight line between the sun and the earth an eclipse of the sun must take place.

4. (A) After being broken down into peptones in the stomach, proteins are changed into amino-compounds in the small intestine.
   (B) Animals get their food directly from plants and indirectly from animals living on plants.
4. (C) Lye is treated to regain the salt and extract the glycerin after the soap has been obtained from the soap kettle.

(D) The large intestine surrounds the small intestine.

(E) The red blood cells are smaller than the white blood cells.

(F) White blood cells fight germs by eating them up.

5. (A) A piece of string, a meter stick, and some weights can make a lever of the first order.

(B) As soon as the digestion of food in the stomach is completed, a ring of muscle at the junction of the stomach with the small intestine relaxes to permit the food to enter the intestine.

(C) An umbra can be formed from a point source of light, an obstacle, and a screen.

(D) In an eclipse of the moon, the shadow of the earth on the surface of the moon looks round; therefore the earth is spherical in shape.

(E) When the process of saponification is completed, the hot soap obtained in the process is allowed to cool before it is made into tablets.

(F) The fact that a brick-red precipitate is obtained when pure starch mixed with saliva is boiled with Fehling's solution, proves that saliva changes starch into glucose.

6. (A) Frogs are a kind of vertibrates.

(B) In soap making, sodium hydroxide breaks down fats into glycerin and fatty acids.

(C) One of the representations of the third order of the lever is the human arm.

(D) The outer skin of man (epidermis) is made up from dead cells to shield the living cells of the inner skin (dermis).

(E) Vitamins and mineral salts guard the body from diseases.

(F) The phases of the moon are caused by the fact that only a part of its illuminated surface can be seen from the earth.

7. (A) A man may suffer from a deficiency of red blood cells if he does not eat a good quantity of food containing iron.

(B) The red blood cells are minute circular biconcave disks.

(C) It will likely be of the second order, if in a certain lever a small effort can support a larger load.

(D) In the human body white blood cells are fewer than red blood cells.
7. (E) The stomach of a mammal is pear-shaped.

8. (A) Adding common salt separates the combination of a fat and an alkali into three layers of soap at the top, migre lye in the middle and lye at the bottom.

(B) A pinhole camera can be made from a wooden box one end of which is covered with a ground glass and the other end provided with a pinhole.

(C) Blood carries oxygen from the lungs to all parts of the human body.

(D) In the second order of the lever the load is between the fulcrum and the effort.

(E) In soap making, salt is regained by evaporation.

(F) Urine is removed from the kidneys to the bladder through the ureter.

9. (A) Because a larger load can be supported by a smaller effort in the second order of the lever, it is used in the wheelbarrow.

(B) Hydrochloric acid, pepsin, and renin constitute the gastric juice of mammals.

(C) It is in hot dry countries that you can see camels used.

(D) Proteins are compounds of oxygen, carbon, hydrogen, and nitrogen.

(E) Soap solution emulsifies fats, hence it washes away dirt.

(F) The tapeworm is a parasite that inhabits the intestine of man.

10. (A) If light were to travel round corners, the sun would have never set.

(B) In mammals the liver extends between the diaphragm and the stomach.

(C) In a lever of the third order, the effort is always greater than the load.

(D) One of the most important functions of the hydrochloric acid in stomach is that it kills harmful bacteria.

(E) The changing colour of the chameleon protects it from being attacked by larger animals.

(F) The penumbra surrounds the umbra.
11. (A) After pumping the molten soap out of the soap kettle, perfumes and colour are added to it.

(B) Since the eclipse of the sun happens only when the sun the moon and the earth are in one straight line, light must travel in a straight line.

(C) Carbohydrates are absorbed after being changed into glucose by the digestive juices.

(D) Mineral salts are an example of a food-stuff.

(E) The grasshopper eats grass, the chicken eats the grasshopper, and man eats the chicken, therefore man gets his food energy from grass.

(F) The fish is a kind of aquatic animal.

12. (A) After running for a mile we feel breathless, accordingly we need more oxygen.

(B) Blood is pumped throughout the body by the action of the heart-beat.

(C) Man is protected from death through loss of blood by the process of blood clotting.

(D) Fat is a compound and hence it must be split to make soap.

(E) The wave-like contractions of peristalsis drives solid and liquid food along the alimentary canal.

(F) Inoculation against diseases is done by introducing weak or dead germs into the body.

13. (A) Acids change blue litmus to red.

(B) Bright smooth surfaces reflect light, while black rough surfaces absorb it.

(C) Blood transports messages of hormones.

(D) Oxygenating blood makes it bright red in colour, and de-oxygenating it makes its colour dull purple.

(E) In the human ear, the sound vibrations are transferred to the brain by the auditory nerve.

(F) Partial and total eclipses are caused by the phenomenon of the umbra and the penumbra.

14. (A) Due to the fact that it is very sweet and harmless, glycerin is used in the production of cakes.

(B) For a healthy living we need a balanced diet of energy and non-energy foods.
14. (C) An application of the second order of the lever is the wheel barrow.
(D) Soap is a detergent.
(E) The eclipse of the moon takes more time than the eclipse of the sun, so the moon is smaller than the earth.
(F) When opening the stomach of a big fish, the skeleton of a tiny fish was found.

15. (A) Air consists of oxygen, nitrogen, and carbon dioxide.
(B) Assimilation starts when digestion is completed.
(C) Sodium and chlorine are the elements forming common salt.
(D) The small intestine is a very long (22 ft. x 1 in.) very much looped tube.
(E) It is only after the food has been broken down into small pieces by the help of the teeth that it can be swallowed.
(F) The heart is situated near the centre of the chest with its narrow end pointing downwards, and slightly to the left.

16. (A) Crocodiles live in fresh water.
(B) It is in a neglected wound that germs can multiply.
(C) The crowbar is a lever of the first order; from that cause its fulcrum must be between the load and the effort.
(D) In the commercial production of powdered soap, liquid soap is pumped through a high pressure nozzle into a blowing chamber.
(E) The gland is an organ, and the liver is a gland, hence the liver is an organ.
(F) The portal vein carries digested food from the intestine to the liver.

17. (A) Electricity breaks down water into oxygen and hydrogen.
(B) In the first order of the lever a small effort may support a larger load.
(C) In the third order of the lever the effort is between the load and the fulcrum.
(D) It is quite possible for one to suffer from indigestion if he eats too much food.
(E) Placing a cardboard with a pinhole in front of a lighted candle will cast its image onto a screen behind the cardboard.
(F) Proteins are transformed into peptones by the action of trypsin.
18. (A) A colourless mass of protoplasm and a central nucleus make up the white blood cell of man.

(B) In a total eclipse of the sun, though the moon is much smaller than the sun, it blocks its light; this proves that the moon is much nearer to the earth than it is to the sun.

(C) Fats are compounds of carbon, hydrogen and oxygen.

(D) Red blood cells outnumber white blood cells, so blood is red in colour.

(E) Reproduction in some unicellular animals and plants is done by a process in which the cell divides into two identical parts.

(F) The blood group of a baby can be different from that of his mother.

19. (A) Fats are split into glycerin and fatty acids by the steapsin secreted by the pancreas.

(B) In a total eclipse of the sun the corona surrounds the sun.

(C) The mucous membrane lining the oesophagus, guards its walls against being scratched by solid food.

(D) The hormone of adrenalin causes blood to clot much faster.

(E) The path of the moon round the earth is elliptical.

(F) When conditions are not favourable in the bowls of a human victim, the amoeba defends itself by forming a tough cyst round itself.

20. (A) Alaklis change red litmust to blue.

(B) Because fats supply the human body with heat, the Escimos eat much fats in their diet.

(C) Birds are vertibrates; ducks are birds; accordingly ducks are vertibrates.

(D) Peptones are transformed into amino-compounds by erepsin.

(E) The earth contains enough material to make eighty-one moons.

(F) The teeth of an adult are more than the teeth of a child.

21. (A) An example of a planet is the earth.

(B) It is probable to train some of the animals living in sea water to adapt themselves to life in fresh water.

(C) Renin curdles milk.
21. (D) The pancreas is a kind of a gland.
(E) The earth can cause an eclipse of the moon.
(F) To live completely on canned food is not advisable, since this may lead to a deficiency of vitamins.
1. (....) IS LIKE (....), (....) IS LIKE (....) AND (....) IS LIKE(....)
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21. (....) IS LIKE (....), (....) IS LIKE (....) AND (....) IS LIKE(....)
II. Perceptual Abstraction Test.

1. Complete the following two diagrams by drawing the digestive system in each case.

2. Draw a diagram showing a white blood cell eating bacteria.
APPENDIX B

RAW SCORES OF THE MAIN ABSTRACTION TEST.
| Category | 0.00 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 10.67 | 11.00 | 11.33 | 12.00 | 12.33 | 13.00 | 13.33 | 14.00 | 14.67 | 15.00 | 15.33 | 16.00 | 16.67 | 17.00 | 17.33 | 18.00 | 18.33 | 19.00 | 19.33 | 20.00 | 20.67 | 21.00 | 21.33 | 22.00 | 22.33 | 23.00 | 23.33 | 24.00 | 24.67 | 25.00 | 25.33 | 26.00 | 26.33 | 27.00 | 27.33 | 28.00 | 28.33 | 29.00 | 29.33 | 30.00 | 30.67 | 31.00 | 31.33 | 32.00 | 32.33 | 33.00 | 33.33 | 34.00 | 34.67 | 35.00 | 35.33 | 36.00 | 36.33 | 37.00 | 37.33 | 38.00 | 38.33 | 39.00 | 39.33 | 40.00 | 40.67 | 41.00 | 41.33 | 42.00 | 42.33 | 43.00 | 43.33 | 44.00 | 44.67 | 45.00 | 45.33 | 46.00 | 46.33 | 47.00 | 47.33 | 48.00 | 48.33 | 49.00 | 49.33 | 50.00 | 50.67 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|----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| 6.00 | 6.50 | 7.00 | 7.00 | 7.00 | 7.00 | 8.00 | 8.00 | 8.00 | 9.00 | 9.00 | 9.00 | 10.00 | 10.00 | 10.00 | 11.40 | 11.70 | 12.00 | 12.30 | 12.60 | 13.00 | 13.30 | 13.67 | 13.90 | 14.20 | 14.50 | 15.00 |
|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1.1  | 1.8  | 2.5  | 2.5  | 2.5  | 2.5  | 3.2  | 3.2  | 3.2  | 3.9  | 3.9  | 3.9  | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   | 4.6   |
| 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   |
| 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   |
| 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   |
| 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4  | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   | 2.4   |

**Summary:**

- **保护率** (Protection Rate):
  - 19.9%
- **百分率** (Percentage):
  - 15.5%

**Groups:**

- 1, 2, 4, 6, 8, 10, 12

**Sentence:**

- A sentence about the table data.
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