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A STUDY OF VERBAL INTERACTION IN SCIENCE CLASSES AND ITS ASSOCIATION WITH PUPILS' UNDERSTANDING IN SCIENCE

This study is concerned with the teaching process. In particular, it is concerned with verbal interaction between teachers and pupils in classrooms, and the effect that the teacher's behaviour has on pupils' development of understanding in science.

Introduction

Much has been written about the teaching process but its nature and the variables related to it are often described in language that Corey (1967) has called "poetic and metaphorical and even mystical" (p. 6). Thus although much has been recorded about the process there is still much to be established about it. In particular, there is much to be learnt about the *relationships* between the behaviours of teachers and pupils and pupil learning, the relative weights to be attached to the teacher and pupil variables which are assumed to be associated with pupil learning, and the effect of various teacher behaviours in promoting pupils' *comprehension within the academic disciplines*. The last mentioned relationship, that is between the actions of teachers and pupils' comprehension, has been neglected as a research field (Gage, 1966), yet it is of obvious importance. For example, from studies of the intellectual content, "the cognitive organization and the logical validity of what teachers say to their pupils and of what the pupils say to their teachers", it may "eventually be possible to formulate a cognitive theory of teaching that will yield us the power we need to understand, predict and improve the ability of teachers to engender comprehension in the academic disciplines" (Gage, 1964). A comprehensive theory of teaching may not emerge until far in the future and the development of this theory will not *necessarily* result in improved control over the teaching process (Travers, 1966). Be that as it may, the present project has been undertaken in the hope that it will add to our knowledge of teaching and to the development of a cognitive theory of teaching.

The protagonists of theories of teaching state that a theory must be empirically based (Gage and Unruh, 1967; Hough, 1967). For this to occur, however, much needs to be known about the nature, patterning and distribution of teacher and pupil behaviour and about the relationships between these behaviours and pupil learning. Before the relationships can be studied, ecological data must be available, and in the last decade, a prevalent research activity has been the collation of ecological data on classroom interactions. Many significant publications have reported on the major contributions to this field of research (e.g. Amidon and Hough, 1967; Amidon and Simon, 1965; Bellack, 1963; Biddle, 1967; Biddle and Ellena, 1964; Meux, 1967; Siegel, 1967). The majority of the studies of classroom interaction have, however, been concerned primarily with the establishment of schemes for classifying classroom behaviour, and as verbal behaviour is the predominant classroom activity, the majority of the schemes deal with verbal behaviour of teachers and pupils. It is only in recent years that some research workers (Flanders, 1967; Tisher, 1968) have studied the associations between verbal behaviour (as described by the schemes) and pupil outcomes.

In these last mentioned projects it is generally expected that growth will occur in pupils as a consequence of classroom experiences. For example, it is expected that cognitive growth will occur in pupils as a consequence of classroom experiences and the teacher is usually viewed as the director or controller of these experiences. It is he who largely determines the way in which pupils are brought into contact with the learning material, the demands made upon pupils' thinking and reasoning operations, and the extent to which pupils' reasoning capacities are challenged and developed. Unfortunately the results of this type of study when it goes on to investigate the effects of teacher behaviour on pupil development are somewhat disappointing, although some associations between verbal behaviour and learning outcomes have been established.

One reason for the disappointing results may be associated with the nature of the behaviour categories studied. In the main the categories (e.g., "inquiry" (Rutherford, 1964), use of advance organizers (Ausubel, 1960, 1963) and problem solving (Wittrock, 1967)) are "molar" units, and each is composed of permutations and combinations of other behaviour units. Thus the behaviours "use of advance organizers", or "inquiry" include several, all, or some of the following activities: repeating a statement, stating a unit, classifying an object, describing an object, reporting an observation, drawing an inference, justifying a statement, and comparing objects or statements. Whether molecular units or different categories are the most appropriate for research on teaching is a critical issue and one that is only recently receiving attention.

Aims

In the study reported here, molecular categories were used to study verbal interaction in science classes and its association with pupils' understanding in science.

The basic aims were:

(a) to identify the nature, distribution and patterning of verbal discourse within some Queensland secondary-school classrooms; and

(b) to investigate, in an exploratory way, the relationship between these ecological data and growth in understanding in pupils.

The first seven sections of this paper deal with some of the findings associated with the first aim and these sections contain a description of the classificatory scheme used, a comparison between Australian and overseas findings and a brief description of the nature of verbal interaction in science lessons in Queensland. Some of the findings associated with the second aim are reported in the remaining sections.

The data were obtained in nine Grade 8 science classes in two State High Schools in Brisbane and fifty-four (six per class) representative lessons were tape-recorded and transcribed. Complete details of the methodology and research design are presented elsewhere (Tisher, 1968). The schools and the pupils were representative of the schools and pupils in the Brisbane metropolitan area. The teachers differed greatly in training and science qualifications and appeared to be representative of the considerable variability in training and qualifications of Grade 8 science teachers. All teachers were non-graduates; four had studied a science subject at University and were continuing with part-time degree work, and three were trained under an emergency post-war teacher training scheme. The heterogeneity in training and science qualifications, and the judgments by the school principals were taken, initially, to imply that a *considerable* variability and range in behaviours would be observed among teachers.

The classificatory scheme

Several schemes have been developed for classifying classroom behaviour (Biddle, 1967) and the majority of these focus on verbal discourse in lessons. Not all the schemes deal with the manner in which the teacher manipulates subject matter, but some that do, e.g. the Bellack scheme (Bellack, Kliebard, Hyman and Smith, 1966) and the Smith and Meux (1962) scheme seem to be appropriate for Australian conditions where a high premium is placed on the development of pupils' understandings in the academic disciplines. As the Brisbane project was concerned with behaviours which describe the manner in which the teacher in interaction with his pupils shapes and charts what is said, and presumably thought, about subject matter, it was decided to use one of the schemes which dealt with cognitive interaction. The methods of classifying verbal behaviours were based on the techniques developed by Smith and Meux (1962) and Nuthall and Lawrence (1965).

Smith and Meux developed twelve major categories which deal exclusively with cognitive interaction. Classroom discourse can be classified into these categories after it has been broken into a series of units called episodes and monologues. An episode, for example, is a unit of verbal interaction or exchanges in which there is a completed verbal transaction between two or more speakers. It is characterized by an initiating or opening phase containing a remark or set of remarks (assertions, questions, invitations, directions) which initiate discussion, a continuing phase which contains claims, questions, or comments resulting from the initiating remarks, and a closing or terminal phase which may contain remarks designed either to supplement preceding statements or to cut off the flow of discussion.

Nuthall and Lawrence (1965) used the Smith and Meux categories but employed a more satisfactory unit of verbal interaction than the episode. This new unit, the incident, was adopted in the Brisbane study. The unit is smaller than the episode and can be more easily identified and categorized. It consists of any question or demand by the teacher and all the subsequent verbal moves which occur up to and including the final response. Any introductory comments preceding the initial question, or terminal comments following the last response, are also included. All transcripts were analysed into incidents and each incident was classified on the basis of the demand made upon the pupils in the initiating or opening move. The Smith and Meux criteria for classification of episodes were used for the classification of incidents. They found that an initiating phase called for a certain type of operation to be performed by pupils, for example, a logical operation of proving, and they classified their twelve major categories in terms of these operations. The categories may be characterized and illustrated as follows (Nuthall and Lawrence, 1965; Smith and Meux, 1962; Meux and Smith, 1964):

Describing

An account of something which has been mentioned or suggested is required; e.g. "Where do scientists look for these fossils?" "What can you tell us about the material which makes up these rocks?" "What do you notice about these animals?"

Designating

Something has to be identified by name—a word or symbol; e.g. "What are the three states of matter?" "What liquid was it that had the lively taste?" "Give an example of a substance which dissolves in water."

Stating

Statements of issues, steps in a proof, rules, conclusions or a statement of affairs are required. Names, descriptions, etc., are not required. For example, the question "What can you conclude from that?" asks for a statement of some sort: it can seldom be answered satisfactorily merely by naming. "What is centripetal force?" "What is the formula for the pressure given these quantities?" "What answer did you get?"

Reporting

A request is made for a report on information contained in some source such as a text-book, or for a review or summary of this or other information; e.g. "Did the book say anything about chitons?" "What was demonstrated in the school broadcast on erosion?"

Defining

Implicitly or explicitly, the meaning of words or terms is demanded; e.g. "If somebody asked you what science was, what answer would you give?" "What is the meaning of 'density of a substance'?" "In H_2O, what does the H_2 mean?" "What is a mollusc?"

Substituting

Students are asked to perform symbolic operations, usually of a mathematical nature; e.g. "I weigh 150 lbs. and my shoes take up an area of 30 square inches. What is the pressure I exert per square inch on the floor?"

Evaluating

An estimate of the worth, dependability, etc., of an object, person, expression, event, action, or state of affairs is required; e.g. "Are they useful wings?" "Do you think that is a satisfactory way to measure friction?" "Are these small holes in the body very important?"

Opining

Students are required to express beliefs or opinions about what is possible, what might have been the case, what could be in the future, whether something is necessary, etc. The students make an inference from evidence rather than a report of a single fact; e.g. "Do you think it (moth) will be able to eat the hard outer shell?" "Can you burrow very far into the earth?" "Does a fish have to live in water?"

Classifying

Explicit reference is made to an instance or class (type, sort, group, set, kind) of things or both, and students are required to place a given instance in the class to which it belongs, or to place a given class in a larger class; e.g. "To which phylum do earth worms belong?" "Would this (granite) be metamorphic, sedimentary or igneous?"

Comparing and contrasting

Students are required to compare two or more things—actions, factors, objects, processes, etc. The initiating phase is usually marked by the presence of such words and expressions as "difference between", "differ from", "be different", "compare", "like", "correspond"; e.g. "What are the differences between plants and animals?" "Just look at that list (of characteristics) and tell me what the important thing is that they are lacking". "Is there any difference in the tongue of these two animals?"

Conditional inferring

A prior condition or antecedent is given and a consequence is asked for, or both the antecedent and consequent are given and the students are asked to affirm or deny the consequent; e.g. "If we connected a wire from here to there and put a meter in between, what happens?" "We've got this force acting downwards and this one acting upwards. What will the resultant be?" "Is hydrogen produced if we place copper in dilute sulphuric acid?"

Explaining

A particular consequent is given and students are required to supply an antecedent.

"To explain is to set forth an antecedent condition of which the particular event or process to be explained is taken as the effect, or else, to give the rules, definitions, or facts which are used to justify decisions, judgments, actions, etc. In the example 'why did the light go out?' the consequent is 'the light go out'. The question asks the student to give a reason (reasons) to account for the fact that the light is out. The reason (s) is the antecedent." (Smith and Meux, 1962, pp. 40-41). Depending upon the type of antecedent used to account for the consequent, sub-categories of explaining may be identified. They are mechanical, casual, sequent, procedural, teleological, and normative. Some examples are: "Why does a suspended magnet point to the north?" "How on earth would it breathe if it hasn't got a nose?" "Why do they live in such shells?"

Many initiating phases have little or no logical significance. They are designed, not to evoke thought, but to keep the classroom functioning and to maintain classroom activities. The final Smith and Meux category, Directing and Managing the Classroom, accounts for these demands. The pupils are asked about reports, homework, or are directed to complete or undertake some task; e.g. "Would you read?" "Was this the question for homework?" "Take this apparatus outside", "Take the reading on the scale."

Examples of incidents appear in the following excerpt from a transcript. Each incident is marked off with brackets [ ] and the category to which it was assigned is designated by a number. The legend appears in the first column of Table 1.

Teacher: . . . [Now, can you give me any others that aren't on the board. Snakes
2 and lizards. Come on.
Pupil: Water snakes.
Teacher: Yes, all sorts of snakes.] [Give me some others that aren't on the board.
2 (Pause) Come on. Yes?
Pupil: Goannas, sir.
Teacher: Yes, he's a type of lizard and crocodiles? Yes, all these things go in together.] [What do you think we could call them? What—you've probably heard of snakes called this sometimes. We could give them a
2 certain name.
Pupil: Reptiles.
Teacher: Yes, that's right and we'll call that class the reptiles. It also has a Latin name a bit like that.
. . .] [Which ones do you think should go with the dog?
2 Come on.
Pupil: Horse.
Teacher: Alright. Well, we'll put a horse with him too.] [Well, let's start at the
8 top of the list. What about whales? Should they go with the dog?

Pupils in Chorus: No Sir!]
Teacher: Who thinks they should go somewhere else?
13 (Some pupils raise hands)]
Teacher: [Who thinks they go with the dog?
13 (A few pupils only raise their hands).]
Well, they're warm blooded animals and they . . .

Comparisons between Australian, American, and New Zealand teachers

Using data from the Smith and Meux (1962) and Nuthall and Lawrence (1965) studies it is possible to make comparisons between Australian, American and New Zealand teachers. These comparisons, though of interest, must be treated with some caution, however, for they are limited by complexities of the classification procedures, the differences in educational setting between the countries and the fact that teachers and classes were not matched.

It is appropriate, too, to note that in Illinois, Smith and Meux analysed transcripts of seventy lessons of which only twenty were records of science lessons. The other fifty-two were records of lessons in mathematics, social studies and English. In New Zealand, Nuthall and Lawrence coded transcripts of eighteen lessons: seven in arithmetic, seven in language and four in spelling and social studies. There were no data for science lessons.

Table 1 contains data for the American, New Zealand, and Australian classrooms and shows the frequency of the various types of initiating phases in episodes or incidents for the American and Australian lessons and for all the questions in the incidents in the New Zealand transcripts. The figures in the table indicate that there are similarities in the distribution of categories in the transcripts from the three countries. A comparison between the distributions for the Illinois and Brisbane science transcripts, for example, indicates a similar emphasis by American and Australian science teachers on explanation and conditional inference, but the percentage of explaining incidents is higher for the American science teachers. Be that as it may, one might have expected explanation to have occurred more frequently for both groups of teachers since at meetings of science teachers, in science teaching journals, and in science curricula, discovery, enquiry, observation, and interpretation of observations are advocated as "essential" and worthwhile behaviours to be fostered. The behaviours which did occur frequently in all samples were the describing and designating ones. In 62 per cent of all incidents the Australian teachers, for example, required their pupils merely to give an account of something, and to identify something by a name, word or symbol. For the American science teachers 48 per cent of the episodes were describing and designating ones.

It is of interest to note that a higher proportion of behaviours were classified as describing, designating and stating in the Australian transcripts (73 per cent) than in either the New Zealand (49 per cent) or American (52 per cent and 47 per cent) ones. The differences are probably dependent, in part, on the nature of the lessons recorded for each sample of classes. When the American and Australian science transcripts are compared, however, the proportion of describing, designating and stating behaviours is still much lower for American (52 per cent) classes than Australian (72 per cent) ones. Many Australian teachers believe this difference is due to the nature of the science course for Grade 8 pupils in Queensland and the emphasis on recall skills in the terminal examinations. Certainly the findings indicate that discovery and enquiry behaviours (i.e., explaining, classifying, comparing and contrasting, evaluating, inferring and the like) are by no means prevalent ones in the Brisbane lessons, despite any claims to the contrary. Whether this finding applies to all Grade 8 science teachers in Australia is an open question, but, if the comparisons with science teachers in

TABLE 1
Distribution of Operations in Initiating Statements
(Percentages)

Operation	Smith and Meux (Episodes)		Nuthall and Lawrence Transcripts	Brisbane Science Transcripts (Initiating questions)
	All Transcripts	Science Transcripts	(All questions)	
1. Describing	25.3	31.4	26	29.7
2. Designating	14.8	17.0	11	32.5
3. Stating	6.8	3.2	12	10.7
4. Reporting	2.9	3.2	2	0.0
5. Defining	4.1	6.1	5	2.1
6. Substituting	0.3	0.4	2	0.3
7. Evaluating	4.6	2.4	4	0.4
8. Opining	5.3	2.2	2	0.7
9. Classifying	3.0	3.2	2	0.8
10. Comparing and Contrasting	3.3	4.6	2	2.4
11. Conditional Inferring	7.3	8.8	7	7.2
12. Explaining	12.9	12.1	11	8.6
13. Classroom Management	9.4	5.4	3	4.6
14. Unclassified	—	—	11	—
	100	100	100	100
Total Number Classified	3,397	935	997	4,487

*These figures were obtained from an analysis of 20 transcripts from four science classes (5 transcripts per class).
The distribution of classes was Grade 10 (1), Grade 11 (2) and Grade 12 (1) (Smith and Meux, 1962).

other countries and other findings (see later sections) are a guide, it seems plausible to state that it does!

Australian data

Table 2 contains the distribution of operations in initiating moves of incidents for the teachers in the Brisbane study. The table shows, for example, that teacher 6 required pupils to designate in 24 per cent of incidents whereas teacher 7 required designation in 37 per cent of the incidents. Also, teacher 5 required explanation in 9 per cent of incidents whereas teacher 7 made this demand in 8 per cent of incidents. The final column in the table contains the distribution of operations for all the teachers and the last row contains the total number of incidents classified for each teacher and all teachers in the study. Teacher 6 made the least number of demands of his pupils and teacher 9 the most. As the average duration of a lesson was 30 minutes the average rate of asking questions ranged from approximately two per minute for teacher 6 to four per minute for teacher 9. If these rates are maintained in other lessons during a day, the pupils are subjected to about 700 questions per school day or 3,000 to 4,000 questions per week! But, it may be argued, the pupils also ask questions of the teacher, and in this way "get their own back". On the contrary, pupils rarely initiate discussion or ask a question. The data in Brisbane showed that the prevalent verbal behaviours of pupils were responses to the teachers' demands. In the study it was found that approximately 95 per cent of the time devoted to talking in lessons was taken up by teacher-talk, and for approximately nine-tenths of each lesson someone was talking. It seems that in Australia we can establish a "law of nine-tenths" for verbal behaviour in classrooms.

Table 2 shows that for all teachers the prevalent behaviours are designating, describing, and stating. These constitute from 62 per cent (teacher 6) to 79 per cent (teacher 7) of all the behaviours. Explaining and conditional inferring are the next most frequently occurring behaviours, but they constitute from only 11 per cent (teacher 7) to 21 per cent (teacher 5) of all the behaviours. If it is assumed that the twelve major Smith and Meux categories can be divided into those teacher behaviours which require pupils to engage in recall (e.g., designating, describing and stating) and into those which demand more than recall from the pupils ("higher-cognitive behaviours") e.g., substituting, classifying, evaluating, and explaining, then the results in Table 2 also show that recall activities predominate in the science classes. In only 23 per cent of incidents did teachers demand more than recall of information from their pupils.

TABLE 2
Distribution of Operations in Initiating Moves: Incident Analysis for All Teachers
(Percentages)

Operation	Teacher									All Teachers
	1	2	3	4	5	6	7	8	9	
Describing	19.3	40.7	29.9	37.5	30.3	26.0	33.7	30.1	22.2	29.7
Designating	40.7	24.5	39.6	28.6	26.1	23.8	37.2	32.8	36.5	32.5
Stating	8.7	11.9	7.2	5.4	15.6	12.6	8.2	8.5	15.4	10.7
Defining	1.8	2.3	3.1	2.9	1.4	4.0	1.8	0.7	1.8	2.1
Substituting	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.3
Evaluating	0.1	1.5	0.2	0.2	0.0	1.1	0.3	0.3	0.0	0.4
Opining	0.9	0.3	1.2	1.0	0.4	1.8	0.8	0.0	0.7	0.7
Classifying	1.2	0.2	1.2	1.5	0.0	0.3	0.3	0.3	1.3	0.8
Comparing and Contrasting	1.5	1.5	0.7	5.4	1.4	2.5	5.4	1.0	2.6	2.4
Conditional Inferring	10.8	7.5	3.3	3.4	11.9	4.0	2.8	8.2	7.8	7.2
Explaining	8.7	4.7	9.8	10.3	9.4	9.4	7.7	10.6	8.5	8.6
Classroom Management	6.3	4.9	3.8	3.8	3.5	9.4	1.8	7.5	3.2	4.6
	100	100	100	100	100	100	100	100	100	100
Total Number Classified	678	653	419	523	571	277	391	293	682	4,487

This division of behaviours into "recall" and "higher cognitive" types is made at an abstract level on the assumption that some behaviours, e.g., designating, do not require the pupil to perform higher-cognitive processes, whereas others, e.g., explaining, do. In an actual classroom, however, these abstract distinctions do not necessarily hold. In class, pupils may respond to the teacher's request to explain by rote recall, and they may respond to the request to describe by some sort of unique analysis and inference. It is difficult when studying classroom interaction to determine whether or not a pupil is involved in recall or whether he is engaged in higher-level thinking. In the Brisbane study it was assumed that this division of the Smith and Meux categories was possible and in the experimental phase of the project the effect of teachers who engage more frequently in higher-cognitive behaviours was studied. As the duration of each lesson observed was thirty minutes, the results in Table 2 imply that the rate at which teachers ask questions ranges, on the average, from one in every thirty seconds to one in every fifteen seconds. The distribution of questions within each lesson, however, was irregular. This feature was gleaned from a study of the coded transcripts and from attempts to construct "flow diagrams".

A second fact of interest was the high degree of similarity in behaviours among teachers. This similarity became evident when rank inter-correlations between teachers were computed and when profiles were drawn for each teacher (Tisher, 1968).

Explaining incidents

Explaining incidents were selected for closer study not only because they ranked highest in frequency of occurrence of the "higher-cognitive incidents" (see Table 2), i.e., incidents which demand more than recall from pupils, but because explanation was assumed to play an important part in the scientific enterprise. The description here will be based on the elements, or moves, within explaining incidents. The moves are questions, replies, and comments, and each explaining incident consists of a sequence of these. The purposes of this examination were, (a) to identify the types of replies pupils gave to questions demanding explanation, (b) to determine how frequently teachers, not pupils, supplied answers to the questions, and (c) to assess the extent to which teachers tolerate inadequate responses, i.e., responses which do not meet the demand of the question.

Nuthall and Lawrence (1965) studied explanation incidents in some detail and they developed categories for the classification of pupils' responses. Their categories were adopted here. The analysis of the explanation incidents, however, was not as detailed as that undertaken by the New Zealand researchers. Attention was focused on the pupils' responses to the "explaining" question in the initiating move and the teacher's subsequent comments or questions.

Thirty-six transcripts (four per teacher) were selected for study and the incidents involving explanation identified. All the Smith and Meux types of explanation were found to occur. The incidents involving procedural explanation were then excluded from the analysis and it was noted that mechanical, causal, and normative explanation accounted for 90 per cent of the remaining incidents. Sequential explanation accounted for only 1.8 per cent.

The types of pupils' responses were tallied and the results appear in column two of Table 3. Seven of the Nuthall and Lawrence (1965) response categories were used. They were:

1. *Aspect or quality.* The response consists of a statement or description of a quality or aspect of the object, procedure, or state of affairs to be explained.
2. *General rule.* The response consists of a general rule or generalization which covers or includes the state of affairs to be explained.
3. *Causal statement.* The response consists of a completed causal statement, or statement of conditional state of affairs.
4. *Action or happening.* The response consists of a description of an action or procedure or something that has happened.
5. *Translation.* The response consists of translation of a state of affairs or word into another idiom or word or phrase with analogous meaning.
6. *Purpose or aim.* The response consists of a description of the purpose or function of a procedure or action.
7. *Irrelevant responses.* The response consists of a description of what the pupil has seen or done or heard of, or other general descriptive statements, which may provide relevant information, but are not attempts at explanation (Nuthall and Lawrence, 1965, p. 42).

The distribution obtained (column two, Table 3) indicates that the responses to the "explaining" questions were heterogeneous.

Also, it was found that the teachers regarded 58 of the total responses to be unacceptable (see columns three and four, Table 3). On 53 of these occasions they indicated this by repeating the initial question. The repeated question was not preceded by any clarifying comment. On the other five "unacceptable" occasions the teachers supplied the answer to the question. The distribution of the 173 acceptable responses is shown in parenthesis in column two of Table 3.

Forty-three per cent of the acceptable responses consisted of completed causal statements (74/173), but 21 per cent of the accepted responses were descriptions of actions or procedures, aspects or qualities of an object, or of a state of affairs. This indicates that teachers "tolerated" replies that did not meet the demand of the question. Also, Aspect and Action and Irrelevant responses found a significant proportion (33 per cent) of the replies to all the questions demanding explanation.

TABLE 3
*Explanatory Incidents Distribution of Type of Pupil Response***

Type of Response	Number of Responses	Unacceptable Responses	
		Question Repeated	Answer Supplied
Aspect	14 (11)	2	1
Rule	43 (41)	2	—
Causal	88 (74)	13	1
Action	26 (22)	4	—
Translation	4 (4)	—	—
Purpose	23 (21)	1	1
Irrelevant	39 (0)	31*	2*
Totals	237 (173)	58	

*On six occasions the teacher asked a new question which did not require pupils to explain.
**Based on 36 transcripts.

These findings imply that teachers need to pay greater attention to the nature of explanations during lessons. It seems, too, that pupils need specific guidance in recognizing what is implied in explanatory questions.

Other ecological data

A finding of interest was the high degree of similarity in behaviours among teachers. This similarity became evident when rank inter-correlations between teachers were computed and when profiles were drawn for each teacher (Tisher, 1968). The finding that they differed little from each other was contrary to the judgments of the school principals who rated the teachers when the project began.

One other feature of the Brisbane transcripts was the prevalence of simple incidents. Complex incidents, that is ones "involving the answering of subsidiary questions within the context of answering one major question" (Nuthall and Lawrence, 1965, p. 21), occurred rarely. One function of complex incidents is the clarification of understandings and misconceptions. In them a teacher can confirm appropriate meanings and associations and correct errors. Thus they play an important role in evaluation. In the transcripts evaluation of pupil responses did occur, but the incidents were generally simple, involving the answering of a single question or demand. The teachers indicated to the pupils by word, or gesture, acceptance or rejection of a response, that an answer was right or wrong. Prevalent teacher responses were:

(a) *Yes/no or right/wrong*

Teacher: What does the C stand for? Yes?
Pupil: Carbon.
Teacher: Yes. What does O stand for?
Pupil: Oxygen.
Teacher: Right. Now, tell me what . . .

(Transcript No. 10 A)

(b) *Repetition of pupil's answer*

Teacher: . . . What sort of charges are they?
Pupil: Negative.
Teacher: Negatives. What do you think two negative charges are going to do? (Pause). Come on. Let's have a bet. Yes?
Pupil: React against each other.
Teacher: React against each other. (Pause). Alright, what are they going . . .

(Transcript No. 12B)

On fewer occasions teachers engaged in a more "open-ended" evaluation by asking pupils to reconsider their replies, e.g.,

Teacher: . . . What would that smallest bit (of water) be like? What would it be?
Pupil: An atom.
Teacher: You think it would be an atom of water? What sort of atom would it be? —a hydrogen atom or an oxygen atom or what?
Pupil: Both together.
Teacher: But you said that it would be one atom. It couldn't be one atom, could it? Could it? Because water is made of hydrogen and oxygen, so if I got down to the smallest bit of water I wouldn't have an atom. What would I have? Yes?
Pupil: A mixture of atoms.
Teacher: Right. Now how many . . .

(Transcript No. 10A)

Parenthetically, it should, perhaps, be said, that the answer finally given by the pupil is not strictly correct.

Teacher warmth or learner-supportiveness

In the hypothesis testing phase of this study a measure of the "warmth" or "learner-support" displayed by the teacher was required, so, in addition to the examination using the modified Smith and Meux technique, the verbal behaviour of the teachers was examined by means of the Withall (1951) scale. On this scale statements made by the teacher are classified into seven categories designated learner-supportive, acceptant or clarifying, problem-structuring, neutral, directive, reproving or disparaging, and teacher-supportive. The criteria for classification of statements are as follows:

1. *Learner-supportive statements*
These are teacher statements that express agreement with the ideas, actions or opinions of the learner or that commend or reassure the learner. The dominant intent of these statements is to praise and encourage the learner.

2. *Acceptant or clarifying statements*
In these statements the teacher accepts and restates the content of the learner's statements. The dominant intent is to help the learner gain insight into the issue.

3. *Problem structuring statements*
These statements are frequently posed as questions seeking further information either to increase the teacher's understanding of what the learner said or to

challenge the learner to give further thought to the issue. These statements tend to sustain the learner by facilitating his problem-solving activities. This is their dominant intent.

4. *Neutral statements*
These include statements in which the teacher questions himself aloud, repeats verbatim comments made by others, uses a polite formality, or discusses some administrative detail.

5. *Directive statements*
These are statements which advise the learner regarding a course of action or his future behaviour. They carry the impression that the teacher expects that the learner will follow his prompting. The dominant intent of the statements is to have the learner adopt a specified behaviour.

6. *Reproving, disapproving or disparaging statements*
By means of these statements the teacher admonishes the learner for unacceptable behaviour and aims to deter him from repeating it. He may impress upon the learner the fact that societal or school standards are not being met. The dominant intent of these statements is to represent to the learner societal values as the teacher sees them and to deter the learner from repeating unacceptable behaviour.

7. *Teacher supportive statements*
In these statements the teacher refers to his own qualifications or achievements in order to confirm his position or his ideas in the eyes of those around him. He may rigidly advocate an idea simply because it is his and despite the call for a re-examination. The dominant intent of these statements is to assert, to defend, or to justify the teacher.

Withall (1951) claimed that a sample of 200 statements uttered by the teacher in the classroom provides a reliable pattern of his verbal behaviour there.

The results from the administration of the Withall scale are summarized in Table 4. Three hundred statements per lesson were obtained from each teacher during two visits to the classroom and three judges classified statements into the Withall categories. The inter-observer correlation coefficient averaged 0.86 and the intra-lesson correlation coefficient averaged 0.79. Teacher-supportive statements did not appear in any of the lessons.

Table 4 contains the percentage of teachers' statements classified as either learner-supportive, acceptant, clarifying, problem-structuring, neutral, directive and reproving. The distribution of statements over categories is given for each teacher. Table 4 shows that the majority of statements for all teachers were classified as problem-structuring and neutral. Sixty-five to eighty-five per cent of all statements were placed into these two categories. The problem-structuring category accounted for all the questions asked, but, as was shown above, the most frequent demand made, or "problem" set, was to require the pupils to recall names, or terms, or other factual information. The neutral category accounted for approximately one-third to one-half (36–59 per cent) of all the teacher's statements. These neutral statements were neither teacher-sustaining, nor learning-sustaining, nor problem-centred.

Withall (1949, 1951) assumed that the categories lie along a continuum from "learner-centredness" to "teacher-centredness", or high to low teacher-warmth. If more of a teacher's statements were classified in the first four categories the classroom climate was said to be learner-centred; if more were classified in the remaining three categories the climate was said to be teacher-centred. The results in Table 4 show that, for all teachers, the majority of statements (54–71 per cent) were classified in the last three categories. Thus, the "social-emotional climate" (Withall, 1949) in all the classrooms was teacher-centred. Teachers did praise, encourage, or support the learner, but warmth or learner-supportiveness was by no means prevalent in these science classrooms. The percentage of the teacher's statements classified as learner-supportive,

TABLE 4
Withall Scale
Percentage of Statements in Each Category

Category	Teacher									Average
	1	2	3	4	5	6	7	8	9	
Learner-Supportive	3	2	9	7	12	6	9	3	2	6
Acceptant	11	13	6	10	7	2	6	5	5	7
Clarifying	1	1	2	0	1	0	0	0	1	1
Problem-structuring	29	30	19	21	26	21	17	21	24	23
Neutral	36	40	37	51	36	57	54	57	59	47
Directive	12	9	17	8	9	12	9	10	4	10
Reproving	8	5	10	3	9	2	5	4	5	6

acceptant or clarifying ranged from eight to twenty per cent. It was shown, too, (Tisher, 1968) that a high degree of similarity existed among the teachers in their classroom behaviour as classified on the Withall Scale.

A pen picture

The discussion in the preceding paragraphs indicates that considerable success was attained with the first aim of the Brisbane study. The modified Smith and Meux technique, for example, led to the presentation of a comprehensive "map" of classroom verbal behaviour and of patterns within this. Data of this kind have high sociological value, in much the same way as data from studies of families, peer groups and clubs do. Certainly, classrooms are important behavioural settings. With very few exceptions, human beings spend a large part of their formative years in them, and on this ground alone a convincing case could be made for the more intensive and more sophisticated study of them. According to another viewpoint (Tisher, 1968), such data also have potential value in furthering our understanding of learning and teaching behaviours. Accepting this view, then, the study can be considered as a contribution to our understanding of the teaching process.

From the findings presented in the preceding paragraphs, a pen-picture of the science teacher and his classroom may be compiled.

Grade 8 science teachers exhibit a high degree of similarity in their behaviour patterns and, on the average, they ask from two to four questions per minute. The questions frequently require the pupils to recall names, terms, and other factual material, and, less frequently, to engage in higher-cognitive behaviours such as classification, explanation, and inference. When explanation is required, not only are a proportion of the pupils' responses irrelevant but the teachers tolerate responses that do not meet the demands of the question. It is rare for students to ask questions of the teacher.

Within the classroom the social-emotional climate is teacher-centred rather than learner-centred, and, though on occasions the teacher is learner-supportive, the majority of the statements he makes have no supportive intent.

Whether this picture applies to all grade 8 science teachers is an open question, and perhaps other research workers will test the conjecture that it does. Other projects will also show whether a high degree of similarity exists among teachers in their classroom behaviour.

Association between verbal discourse and growth in understanding

The second aim of the study was to investigate in an exploratory way the relationship between teacher behaviour and growth in understanding in pupils. The twelve major Smith and Meux classificatory categories were divided into those teacher behaviours which would seem to require pupils to engage in recall and higher cognitive behaviours and it was postulated that, other things being equal, teachers who engage more frequently in higher cognitive behaviours will foster a greater understanding in pupils than teachers who less frequently engage in these behaviours. An attempt was made to examine this postulate.

The teacher, however, is not the only one exerting "psychological force" (Gage, 1967) in the classroom. The pupils often contribute directly to their own cognitive growth through their purposive behaviour, and at other times they "filter" the contribution of the teacher. The study makes use of both of these leading ideas and its theoretical basis (Tisher, 1968) could be described in the following way:

Within a classroom the teacher's verbal behaviour is an important factor in helping to develop the pupils' understanding in a subject. The effect of the teacher's behaviour is modified, however, by various pupil variables. Depending on the effect of the interaction between the teacher and the pupil variables, the development of pupils' understandings will be enhanced or inhibited.

Pupil variables, which, according to the available research evidence, modify the effects of a teacher's behaviour, may be grouped into three categories. The first group contains those variables associated with *personality orientations*, the second, those associated with *personal structures and stores of knowledge*, and the third, those associated with *abilities* to classify, transform, and store information. The variables selected for examination were taken from each of the three categories. Here reference is made to three only of these variables—achievement orientation, prior-knowledge-in-science, and ability; others selected include attitude to science and flexibility.

Personality orientations: achievement orientation

Differences in pupils' responses to particular styles of instruction have been shown to be associated with differences in personality orientations (Beach, 1960; Wispe, 1953). In particular, differences in achievement orientation have been shown to affect pupils' responses to particular styles of instruction. The studies by Bush (1954) and Della-Piana and Gage (1955), for example, indicate that many pupils who rate high in achievement orientation respond most favourably to teachers who emphasize mastery of information. Other pupils respond most favourably to friendly and considerate teachers. Bush (1954) claims that a more effective educational relationship is established between teachers and pupils when achievement-oriented pupils are taught by subject-oriented teachers.

Personal structures and stores of knowledge

Psychological theories and a number of research studies (Ausubel, 1963) have substantiated that the extent and organization of a pupil's existing store of knowledge of subject matter affect subsequent learning. Mallison (1964), for example, found that students whose achievement in science was low in the early years at secondary school tended to be low in achievement in science later in high school. He suggested that lack of knowledge in science in the earlier years inhibited subsequent development of understanding in the subject. Also, Ausubel and Fitzgerald (1961) have shown that there is a relationship between a pupil's existing degree of knowledge and the learning of unfamiliar material in the same subject-matter field. Ausubel (1963) says that general background knowledge probably facilitates learning and retention by increasing the familiarity of the new material, and hence the learner's confidence in coping with it.

Ausubel (1963) advocates certain teacher behaviours aimed at fostering greater understanding in a subject. These include cross-linking of ideas in cognitive structure, classification of significant similarities and differences between new and established ideational content, and reconciliation of real or apparent inconsistencies between new and established ideas. Processes of exploration, classification, and reconciliation, says Ausubel, influence cognitive structure by affecting the stability and clarity of knowledge in a particular subject-matter field. When cognitive structure is stable and clear, and also suitably organized, valid unambiguous meanings emerge. These meanings tend to remain discriminable from the ideational contents which subsume them.

Abilities to classify, transform and store

An interaction between teacher behaviour and pupil ability was reported by Gallagher and Aschner (1963). Using twelve classes of pupils of high intellectual ability they attempted to relate the type of teacher questions to the production of divergent thinking on the part of pupils. They found, in general, that when the percentage of divergent questions was high, the percentage of divergent thinking produced was also high. Conversely, when the percentage of divergent questions was low, the divergent thinking produced was also low. In a study of 4th grade science classes, Schantz (1963) reported on the effects of interactions between indirect and direct teaching and pupil ability. She found that high-ability children exposed to indirect teacher influence scored significantly higher on a criterion science test than did the high-ability children exposed to direct teacher influence. Sears and Hilgard (1964) also report the effect of interaction between pupil ability and various teacher behaviours. They indicate that for children of superior mental ability certain teacher behaviours seem to be effective in producing gains in achievement. These behaviours included the frequency with which the teacher emphasized the expanding and amplifying of ideas, giving alternatives and possibilities rather than straight statement of facts, and also the extent to which the teacher listened to the child.

The results from some studies on the effects of various methods of instruction indicate that the high-ability pupils achieve equally well under each method, and that in each teaching situation their achievement is greater than that of low-ability pupils (Doty, 1967; Geller, 1963; Oliver, 1965).

On the basis of the findings and arguments in the preceding paragraphs it was assumed that, other things being equal, the development of understanding in science will be greatest for pupils high and low in achievement-orientation, prior-knowledge in science and ability, when they are taught by teachers who frequently make higher-cognitive demands, and least when they are taught by teachers who less frequently make these demands. The results from the testing of these hypotheses are reported below.

However, the results of the research referred to above also suggest that behaviours other than those specified in the hypotheses are necessary to enhance the development of understanding. Teacher warmth, i.e., teacher behaviour which demonstrates friendliness, affection, and support for pupils, also appears to be effective. Certainly when the variety of studies on teacher warmth are considered (e.g., Reed, 1961, 1962; Cogan, 1958), there appears to be an association between teacher warmth and pupil growth, but the evidence is not conclusive. Reed (1961, 1962) measured teacher warmth by those behaviours which relaxed interpersonal tension between teacher and pupils. He found that there was a significant positive relationship between teacher warmth and pupils' science interests as assessed by a measure of the students' out-of-school activities in science. Solomon (1966) in a study of 229 teachers of adult evening courses identified ten bi-polar teacher-behaviour factors of which factor 5, "warmth", or "approval versus coldness", was one accounting for five per cent of the total variance. Though the factor was found to be significantly related to the course area (for example, social science teachers and humanities teachers exceeded chance frequencies in coldness and warmth respectively), there was no significant correlation between this factor and student gains on a criterion test (Solomon, Bezdek and Rosenberg, 1963; 1964). On the other hand, Christensen (1960) in a study involving 4th grade pupils and their teachers, established that there was a significant relationship between teacher warmth and pupils' growth in achievement in vocabulary and arithmetic. Although this finding must be treated with some caution because the experimental sample was small and non-random, the result supports the general contention that teacher warmth is related to pupil outcomes.

From the Solomon and Christensen studies one might infer that teacher warmth is significantly related to the achievement of younger rather than older students. The results from other studies (Bush, 1954; Della-Piana and Gage, 1955; Ryans, 1961), however, indicate that a significant relationship may occur between teacher warmth and the productive behaviour and achievement of *some* older pupils. Ryans (1961), for example, established the existence of a low positive correlation between teacher warmth and the productive behaviour of secondary-school pupils. Also, the results from Bush's (1954) research suggest that a more effective educational relationship will be established between teachers and secondary pupils when pupils who are low in achievement and who seek acceptance and approval within the classroom setting are taught by a "warm" teacher. On the other hand, a more effective educational relationship will be established between teachers and secondary pupils when achievement-oriented pupils are taught by teachers who are primarily subject-oriented.

On the basis of the preceding discussion it was assumed, that, other things being equal, the development of understanding in science will be greatest for high achievement-oriented pupils when they are taught by teachers rated low in warmth and least when they are taught by teachers high in warmth. The converse applies for pupils who are low in achievement orientation. The results from the testing of this hypothesis, too, are reported below.

Testing of hypotheses

The basic research design for the hypothesis-testing phase of the study was a non-equivalent control group one (Campbell and Stanley, 1963). The project, however, was a naturalistic one (Baldwin, 1965) in the sense that variables were not manipulated by the research worker. Naturalistic studies have an advantage in that they avoid what Brunswik (1955) has called the artificial tying and untying of variables.

Using the ecological data the teachers were classified as either high or low in warmth, and into three groups (high, medium, and low) according to the frequency of their higher-cognitive demands. The hypotheses were tested using a two-way analysis of variance (ANOVA), and, as there were unequal cell frequencies, the least squares method (Winer, 1962) was used. For each analysis pupils were divided into high and low groups on the basis of their scores on the pupil-variable under consideration. Pupils with scores above the median were classified as high, and those with scores below, as low. The remainder with scores equal to the median, were classified alternately as high and low.

A criterion science test (Appendix), an attitude scale (Adams, 1962), a prior-knowledge-in-science test (based on the STEP series), Raven's Progressive Matrices (A.C.E.R., 1958) and the California Psychological Inventory (Gough, 1964) were administered to 338 grade 8 pupils in nine classes in Brisbane, and complete data were obtained from 168 (92 females, 76 males). The criterion test was administered as a pre-test (February) and post-test (November) and residual scores were calculated for each pupil using regression analysis. Control of variables was achieved by this technique (Tisher, 1968). The residual scores were interpreted as those parts of the final criterion score due to teacher behaviour and the pupil variable under consideration (e.g., pupils' prior knowledge in science). The residual scores used in each ANOVA were calculated from separate regression analyses. For example, when the interaction between ability and teacher behaviour was analysed, the residual scores were calculated using a regression analysis in which ability was not an independent variable.

As this part of the study was exploratory, rigid adherence to traditional procedures of reporting results was not maintained. There were two departures from tradition. First, although convention was followed by choosing the .05 level of significance for the hypothesis testing, the level was not regarded as sacred (Skipper, Guenther and Nass, 1967). For example, some values which fall slightly below the level are reported for the interest of readers. This procedure receives support from Labovitz (1968) and Skipper, Guenther and Nass (1967) who argue against the sacredness of .05. Nevertheless, findings were regarded as supporting the hypotheses only when they were significant at the .05 level. Second, although it is traditional to refrain from making t-tests on differences between means when the corresponding F of the ANOVA is not significant, in several instances this procedure was not followed. The departure was considered to be justified where the theoretical basis suggested that directional differences should occur. Winer (1962) advocates a similar practice. He states (p. 208) that specific comparisons which are suggested by the theoretical basis for the experiment can and should be made individually, regardless of the outcome of the corresponding F test.

Hypothesis 1

> The development of understanding will be greatest for the high achievement-oriented pupils when they are taught by teachers rated low in warmth and least when they are taught by teachers high in warmth. The converse applies for pupils who are low in achievement-orientation.

Data and results of computations relevant to this hypothesis appear in Tables 5 and 6. Table 5 summarizes the results for ANOVA with teacher warmth and pupil achievement-orientation, and Table 6 shows the mean residual scores and number of pupils (N) for each group.

The significance of the difference between pairs of group means in Table 6 was tested using the t statistic and the standard error of the mean of each cell was estimated from the mean square within cells (Lindquist, 1956). This technique assumes homogeneity of error variance which may not be met in all groupings in this study. However, the t-test is robust with respect to moderate departures from the hypothesis of homogeneity of variance (Winer, 1962).

A convention has been adopted for specifying means in tables similar to Table 6. First, cells are numbered by columns from left to right and then row by row in each table. Second, "M" with these numbers as sub-scripts is taken to refer to the mean of the cell. For example, in Table 6, M_{II}= mean for cell II in column 2 and row 1, and M_{III}= mean for cell III in column 1 and row 2.

The results in Table 6 show that teacher warmth and pupil achievement-orientation do not affect the development of pupils' understanding in science and that there is a significant interaction between warmth and achievement-orientation. The directions of the differences between pairs of means in Table 6 are as predicted but only the differences between M_{III} and M_{IV}, and M_{II} and M_{IV} are significant at the .05 level.

TABLE 5
ANOVA: Warmth, Achievement Orientation
(Residual Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Warmth (W)	10.20	1	10.20	0.32	p>.10
Achievement Orientation (A)	59.15	1	59.15	1.86	p>.10
W × A	259.99	1	259.99	8.18	p<.01
Error	5,211.94	164	31.78		

TABLE 6
Cell Means for ANOVA: Warmth, Achievement Orientation
(Residual Scores)

Pupil Group	Teacher Group	
	High Warmth	Low Warmth
High Achievement Orientation	10.45 (N=50) I	12.51 (N=34) II
Low Achievement Orientation	11.44 (N=45) III	8.47 (N=39) IV

For $M_{III}-M_{IV}$, $t = 2.39$ ($p<.02$)
$M_{II}-M_{IV}$, $t = 3.08$ ($p<.01$)
$M_{II}-M_{I}$, $t = 1.66$ ($.05<p<.10$)

The results provide support for hypothesis 1. First, the development of understanding in science is greatest for the low achievement-oriented pupils when they are taught by teachers rated high in warmth and least when they are taught by teachers low in warmth. Second, the effect of the teachers who are low in warmth is greater with the high rather than the low achievement-oriented pupils.

The criterion test may be divided into two groups of items, recall and high-cognitive (Tisher, 1968), and analyses of variance may be made using both residual recall and residual higher-cognitive scores. (The correlation between residual recall and residual higher-cognitive scores for two sets of regression analyses was of the order of 0.08).

When residual recall and residual higher-cognitive scores were used in ANOVA the results shown in Tables 7 and 8, and 9 and 10, were obtained. The results in Table 7 involving the residual higher-cognitive scores show that teacher warmth and pupil

TABLE 7
ANOVA: Warmth, Achievement Orientation
(Residual Higher-Cognitive Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Warmth (W)	1.87	1	1.87	0.10	p>.10
Achievement Orientation (A)	8.77	1	8.77	0.46	p>.10
W × A	59.96	1	59.96	3.14	.10>p>.05
Error	3,128.86	164	19.08		

TABLE 8
Cell Means for ANOVA: Warmth, Achievement Orientation
(Residual Higher-Cognitive Scores)

Pupil Group	Teacher Group	
	High Warmth	Low Warmth
High Achievement Orientation	3.92 (N=50) I	4.93 (N=34) II
Low Achievement Orientation	5.51 (N=45) III	3.11 (N=39) IV

For $M_{II}-M_{IV}$, $t = 1.78$ ($.05<p<.10$)

achievement-orientation do not affect pupils' higher-cognitive gains on the criterion. Also, there is no significant interaction between warmth and achievement-orientation. The directions of the differences between pairs of means in Table 8 agree with the predictions in hypothesis 1.

The results involving residual recall scores (Tables 9 and 10) show that teacher warmth and pupil achievement-orientation do not affect pupils' recall gains, and that there is a significant interaction between warmth and achievement-orientation. The directions of the differences between pairs of means in Table 10 agree with the predictions in hypothesis 1. When a two-tailed test is applied only the differences between M_{III} and M_{IV}, and M_{II} and M_{IV} are significant at the .05 level. These findings for residual recall and residual higher-cognitive scores substantiate those above, and provide support for hypothesis 1.

Gough (1964) has reported that Ac, rather than Ai, was associated with successful achievement in high school. This was not so in the Brisbane study. Product moment correlations between Ac, Ai, and pupils' scores on the criterion test were as follows:

for post-test score with Ac, $r = 0.11$
for post-test score with Ai, $r = 0.26$

For a one-tailed t-test, values of $r0. \geqslant 18$ are significant at the .01 level, and values of $r \geqslant 0.12$ are significant at the .05 level.

To test whether Ac or Ai affected pupils' development of understanding in science, two-way analyses of variance were computed in which these measures were used to group pupils. The only significant result obtained was for the interaction between teacher warmth and Ac using residual recall scores. The results of this ANOVA are summarized elsewhere (Tisher, 1968). The findings, however, not only provide support for hypothesis 1 but allow the earlier findings to be qualified as follows:

first, the development of understanding in science (*recall*) is greatest for the low Ac pupils when they are taught by teachers rated high in warmth and least when they are taught by teachers low in warmth;
second, the effect (*on gains in recall*) of the teachers who are low in warmth is greater with the high rather than the low Ac pupils.

Hypothesis 2

The development of understanding will be greatest *for high and low achievement-oriented pupils* when they are taught by teachers who frequently make higher-cognitive demands, and least when they are taught by teachers who less frequently make these demands.

Data and results of computations relevant to this hypothesis appear in Tables 11 and 12. Pupils were allotted to achievement-orientation groups on the basis of their scores on both Ac and Ai scales of the California Psychological Inventory. Pupils high on Ac ("achievement via conformance") display factors of interest and motivation which facilitate achievement in any setting where conformance is a positive behaviour.

TABLE 9
ANOVA: Warmth, Achievement Orientation
(Residual Recall Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Warmth (W)	3.19	1	3.19	0.43	$p > .10$
Achievement Orientation (A)	21.53	1	21.53	2.90	$p > .10$
W × A	71.92	1	71.92	9.68	$p < .01$
Error	1,218.62	164	7.43		

TABLE 10
Cell Means for ANOVA: Warmth, Achievement Orientation
(Residual Recall Scores)

Pupil Group	Teacher Group	
	High Warmth	Low Warmth
High Achievement Orientation	6.51 (N = 50) I	7.58 (N=34) II
Low Achievement Orientation	6.94 (N=45) III	5.36 (N=39) IV

For $M_{III}-M_{IV}$, $t = 2.63$ ($p<.01$)
$M_{II}-M_{IV}$, $t = 3.47$ ($p<.01$)
$M_{II}-M_{I}$, $t = 1.75$ ($.05<p<.10$)

Pupils high on Ai ("achievement via independence") display factors of interest and motivation which facilitate achievement in any setting where autonomy and independence are positive behaviours (Gough, 1964).

The results show that neither teacher behaviour nor pupil achievement-orientation affect the development of pupils' understanding in science and that there is no significant interaction between teacher behaviour and achievement-orientation. With the exception of ($M_{II} - M_{I}$) and ($M_{V} - M_{IV}$) differences between pairs of means (Table 12) are in the predicted directions.

These findings do not provide support for hypothesis 2.

Hypothesis 3

The development of understanding will be greatest *for pupils high and low in prior knowledge* in science when they are taught by teachers who frequently make higher cognitive demands, and least when they are taught by teachers who less frequently make these demands.

Data and results relevant to this hypothesis appear in Tables 13 and 14. The results show that prior-knowledge-in-science affects development of understanding in science. The difference M_{II}—M_{V} (Table 14), which is significant at the .05 level (two-tailed t-test) suggests that the effect of the medium teachers is greater with pupils whose prior-knowledge-in-science is high rather than low.

The results in Table 13 show also that teacher behaviour does not affect development of understanding in science and that there is no significant interaction between teacher behaviour and prior knowledge. These findings (Tables 13 and 14), which do not provide support for hypothesis 3, suggest that pupils high *and* low in prior knowledge gain equally when taught by teachers who rate *high* or *low* in higher-cognitive demands.

Probably there are several reasons for the failure to substantiate the theory. The

TABLE 11
ANOVA: Teacher Demands, Achievement Orientation
(Residual Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Demands (D)	83.86	2	41.93	1.27	p>.10
Achievement Orientation (A)	55.63	1	55.63	1.69	p>.10
D × A	77.96	2	38.98	1.19	p>.10
Error	5,327.81	162	32.89		

TABLE 12
Cell Means for ANOVA: Teacher Demands, Achievement Orientation
(Residual Scores)

Pupil Group	Teacher Group: Higher-Cognitive Demands		
	High	Medium	Low
High Achievement Orientation	9.99 (N=22) I	13.66 (N=20) II	10.81 (N=42) III
Low Achievement Orientation	9.77 (N=24) IV	10.25 (N=23) V	10.14 (N=37) VI

For $M_{II}-M_{I}$, $t = 2.07$ ($p<.05$)
$M_{II}-M_{V}$, $t = 1.96$ ($p = .05$)
$M_{II}-M_{III}$, $t = 1.83$ ($.10>p>.05$)

most important of these is that although care was taken to choose teachers who were likely to differ in teaching style, the differences were, in fact, very small. In order to proceed with the hypothesis testing, it was necessary to differentiate among the group of teachers, but the differentiation did not provide extreme groups. In addition to this lack of teacher variability there was another "handicap" under which this hypothesis-testing exercise laboured. It was the failure of almost all teachers to capitalize on existing knowledge of pupils. It was found (Tisher, 1968) that teachers rarely used organizers or advance organizers, and also, that, when they integrated ideas, they merely required pupils to relate present learning material to previously learned ideas through the recall of factual information. This failure to capitalize on pupils' prior-knowledge-in-science may have affected the findings associated with hypothesis 3.

TABLE 13
ANOVA: Teacher Demands, Prior Knowledge
(Residual Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Demands (D)	71.77	2	35.79	1.11	p>.10
Prior Knowledge (PK)	188.35	1	188.35	5.87	p.V.05
D × PK	75.94	2	37.97	1.18	p>10
Error	5,200.98	162	32.10		

TABLE 14
Cell Means for ANOVA: Teacher Demands, Prior Knowledge
(Residual Scores)

Pupil Group	Teacher Group: Higher-Cognitive Demands		
	High	Medium	Low
High in Prior Knowledge	10.26 (N=19) I	13.89 (N=23) II	11.34 (N=42) III
Low in Prior Knowledge	9.60 (N=27) IV	9.54 (N=20) V	9.54 (N=37) VI

For $M_{II}-M_{V}$, $t = 2.51$ ($p<.05$)
$M_{II}-M_{I}$, $t = 2.15$ ($p<.05$)

Hypothesis 4

> The development of understanding will be greatest *for the able and less able* students when they are taught by teachers who frequently make higher-cognitive demands, and least when they are taught by teachers who less frequently make these demands.

The results relevant to this hypothesis appear in Tables 15 and 16. The measure of pupil ability used in this instance was based on the scores of pupils on the A.C.E.R. Inter D (Clark, 1958).

Table 15 shows that teacher behaviour and intellectual ability affect pupils' development of understanding in science and that there is an interaction between teacher behaviour and ability.

The results in Table 16 show that several of the differences between pairs of means are in the predicted directions. Of these, the significant difference $M_{II} - M_{III}$, for example, suggests that gains in understanding will be greatest for the able pupils when they are taught by teachers rated medium rather than low in higher-cognitive demands. The results also show that the gains of the able pupils are greater than the gains of the less able when both are taught by teachers rated high and medium in higher-cognitive demands. Other significant differences ($M_{II} - M_{I}$ and $M_{VI} - M_{IV}$, Table 16) are not in the expected direction. It appears, for example, that when the able pupils are taught by teachers who rate high in higher-cognitive demands their development of understanding in science is *inhibited*. There is no clear explanation of this finding, but teachers rated high in higher-cognitive demands were particularly prone to accept irrelevant answers, or ones that did not meet the full demands of the question. It might be that the able pupils noted the inconsistencies between the teacher's demands and pupils' responses, became confused and consequently were inhibited in their growth of understanding in science. Able pupils might be expected to reconcile

TABLE 15
ANOVA: Teacher Demands, Inter D
(Residual Scores)

Source of Variation	Sum of Squares	Df	Mean Square	F Ratio	p
Teacher Demands (D)	213.70	2	106.85	3.22	$p<.05$
Inter D (I)	344.65	1	344.65	10.38	$p<.01$
D × I	192.92	2	96.46	2.91	$.10>p>.05$
Error	5,377.93	162	33.20		

TABLE 16
Cell Means for ANOVA: Teacher Demands, Inter D
(Residual Scores)

Pupil Group	Teacher Group: Higher-Cognitive Demands		
	High	Medium	Low
High Inter D	10.89 (N=20) I	14.65 (N=23) II	10.72 (N=41) III
Low Inter D	6.87 (N=26) IV	8.98 (N=20) V	10.03 (N=38) VI

.. For $M_{II}-M_{I}$, $t = 2.14$ ($p<.05$)
$M_{VI}-M_{IV}$, $t = 2.14$ ($p<.05$)
$M_{II}-M_{III}$, $t = 2.62$ ($p<.01$)
$M_{I}-M_{IV}$, $t = 2.34$ ($p<.02$)
$M_{II}-M_{V}$, $t = 3.22$ ($p<.01$)

the perceived inconsistencies by solving problems themselves, but the predominant classroom activity in this study was recall of information, with relatively little time devoted to skills associated with problem-solving, i.e., to evaluation, classification, inference, and explanation. Problem-solving skills would, therefore, be inadequately developed, and the pupils would be less able to reconcile perceived inconsistencies.

The findings provide some, though not unequivocal, support for hypothesis 4.

Conclusion

The hypothesis-testing exercises proved to be interesting and worthwhile, although only a small number of hypotheses were confirmed. Several reasons for the failure to achieve complete success with the theoretical predictions were stated above. Given these, and possibly other handicaps, it would be unrealistic to expect that all the hypotheses would be unequivocally supported; perhaps the best that one could hope for would be "trends" in line with the hypotheses. These trends appeared in almost all cases, and they justify the retention of the hypotheses, as hypotheses, when more carefully controlled *experimental* studies are undertaken.

Some significant and interpretable results were obtained. These included:

1. The development of understanding in science is greatest for the low achievement-oriented pupils when they are taught by teachers rated high in warmth and least when they are taught by teachers low in warmth.
2. The gains of the high achievement-oriented pupils are greater than the gains of the low achievement-oriented pupils when both are taught by teachers low in warmth.
3. Recall gains are greatest for the low achieving-by-conforming pupils when they are taught by teachers rated high in warmth, and least when they are taught by teachers low in warmth.
4. The effect on gains in recall of teachers who are low in warmth is greater with the high rather than the low-achieving-by-conforming pupils.
5. The effect on gains in understanding of teachers who are medium in higher-cognitive demands is greater with pupils whose prior-knowledge-in-science is high rather than low.
6. Gains in understanding of the able pupils are greater than the gains of the less able when both are taught by teachers rated high and medium in higher-cognitive demands.
7. Gains in understanding are greatest for the able pupils when they are taught by teachers rated medium rather than low in higher-cognitive demands.

The findings of this study have implications for the training of teachers. The ecological data, for example, may be taken to imply that greater attention should be given to the verbal behaviours of teachers and that in pre-service and in-service courses skills in questioning (especially "higher-cognitive questioning") be developed. It seems, too, that teachers' skills in evaluation need to be developed. There is a need, for example, to foster more "open-ended" evaluation by teachers and a need to encourage them to give greater guidance to students in recognizing what is implied in questions (e.g., in explanatory questions).

The experimental data have implications for teaching. The findings relating to hypothesis 1, for example, provide support for Thelen's (1967) view of "grouping for teachability". It was shown that the development of understanding is enhanced when low achievement-oriented pupils are taught by teachers high in warmth and when high achievement-oriented pupils are taught by teachers low in warmth.

Finally, two general comments on studies of this kind might be made. First, although there is a case for naturalistic, ecological studies they provide information only about teaching *as it is*. Any training programme which might eventuate in the future from such data would have, as the standard, the performance of the more effective teachers, and there would, among other things, be no guide to improvement for these. There is a need, therefore, to study the effects of *new* teacher behaviours. Gage (1966) and Meux (1967) suggest that one way of obtaining these "new" behaviours is to use existing behaviours or strategies combined in ways not presently observed, and they believe that these combinations may result in teaching strategies which are far more effective than those presently used by our best teachers. However, care needs to be exercised lest the "errors" of some experimental psychology (e.g., the artificial tying and untying of variables) be repeated. One experiment, following the lines of the Gage and Meux proposal, has been reported (Nuthall, 1968).

A slight variation of the Gage and Meux suggestion is to set up a model of the teaching process, design experiments to test the model, and train teachers to master the teaching model rather than model the master teacher. This approach to research in teaching and to the education of teachers is advocated by Stolurow (1965) and Campbell (1968).

The second general comment is that studies such as this one deal with only a small, albeit important, segment of teaching. The selected events and behaviours are taken from a complex of ongoing activities which is seldom studied in its entirety. Perhaps a glimpse at the "hidden" elements of teaching may increase understanding of some of the more visible and well-known features of the process.

It has been said (Jackson, 1966) that "our present knowledge of what goes on in the classroom resembles in many ways the traveller's impressions of a foreign country obtained by taking a one-hour bus ride through its major city" (p. 23). However, the research currently being undertaken is making a contribution to our understanding of teaching, and the future looks brighter, if more challenging, than ever before.

Acknowledgments

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Appendix

The Criterion Science Test

The test items

The criterion test was administered as 3 sub-tests of 26 items each. The judges' classification for each item is recorded in brackets, e.g. (Recall), (Application) and the required alternative is marked with an asterisk.

Item analysis details appear at the end of each question.

p = proportion of pupils passing an item and

r_{pbi} = point-biserial correlation.

Item statistics are based on test scores from 1,600 grade 8 pupils.

Understanding in Science

Directions preceding each sub-test

This is a test of some of the understandings you have been developing in science. Here are a few suggestions which will help you earn your best score.

1. Make sure you understand all the directions which follow.
   You may ask questions about any part of the directions you do not understand.
2. Work carefully and at a steady pace; do not spend too much time on any one item. If a question seems too difficult, make the most careful guess you can, rather than waste time puzzling over it. You will make your best score by answering every question.
3. If you finish before the time is up, go back and spend more time on those questions about which you were most doubtful.

Scoring the answer sheet

Each question on the test paper is followed by five suggested answers. You are to choose the answer you think is correct and mark your choice on the separate answer sheet by shading in the space as shown for the worked example below.

THE TEST PAPER IS NOT TO BE MARKED IN ANY WAY.

Worked example

Question: Which of the following statements is CORRECT?
The planet Mars is
(a) 93 million miles from the Earth
(b) the fourth planet in the solar system in order from the Sun
(c) the closest planet to the Sun in the solar system
(d) the furthest planet from the Sun in the solar system
(e) the seventh planet in the solar system in order from the Sun

The correct answer is (b) and the space below (b) on the answer sheet has been shaded in.

Now try one by yourself.

Trial Example Mark your answer in the space marked "Trial Example" on the answer sheet.

Question: The study of life or living things is known as
(a) Zoology
(b) Morphology
(c) Biology
(d) Physiology
(e) Ecology

On the answer sheet you should have shaded the space below (c).

Mark only one answer for each question.
If you wish to alter an answer cross out the unwanted answer with one single line like this, -/-/- .
If you have any questions ask them now.

DO NOT TURN THIS PAGE TILL TOLD TO DO SO.

Sub-Test C1

1. Repulsion between two bar magnets occurs when
   (a) unlike poles are placed together
   (b) the two magnets are heated
   (c) the North pole of one is placed near the South pole of the other
   (d) the magnets are suspended end to end
   *(e) the North pole of one is placed near the North pole of the other
(Recall) $p = 0.83$ $r_{pbi} = 0.34$

2. A fracture in the Earth's crust along which the rocks moved in relation to each other is called a
   (a) compression
   (b) fold
   (c) creep
   (d) thrust
   *(e) fault
(Recall) $p = 0.66$ $r_{pbi} = 0.40$

3. A light year is
   (a) the time taken for light to travel 186,000 miles
   (b) the time taken for light from the Sun to reach the edge of our galaxy
   (c) the distance from the Sun to its nearest neighbour star
   *(d) the distance light travels in one year
   (e) the distance light travels in 186,000 seconds
(Recall) $p = 0.61$ $r_{pbi} = 0.39$

4. A reddish-brown deposit left in a container from which water has evaporated indicates that the water most likely contained dissolved
   (a) sodium chloride
   (b) limestone
   (c) calcium compounds
   (d) phosphorus compounds
   *(e) iron compounds
(Draw Conclusion) $p = 0.53$ $r_{pbi} = 0.47$

5. Birds that catch insects in flight have beaks that are
   *(a) short and wide
   (b) curved and sharp
   (c) long and thick
   (d) short and thick
   (e) long and narrow
(Application) $p = 0.41$ $r_{pbi} = 0.50$

6. A sample of water which an astronaut had brought back from the planet Mars was tested in a laboratory on Earth. Its boiling point was recorded as 100.2°C before distillation and 100°C exactly after distillation. It is reasonable therefore to conclude that

(a) the air pressure changed between thermometer readings
(b) the sample of water was pure
*(c) the sample of water contained impurities
(d) the thermometer was reading high
(e) the thermometer was reading low
(Application) $p = 0.55$ $r_{pbi} = 0.39$

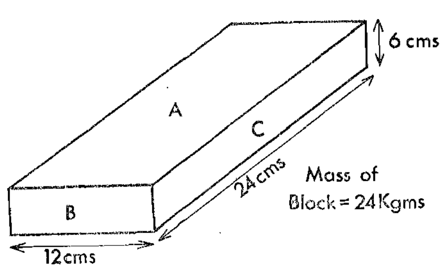
7. In the atmosphere surrounding the Earth the region of weather is called the
(a) stratosphere
*(b) troposphere
(c) lithosphere
(d) ionosphere
(e) photosphere
(Recall) $p = 0.45$ $r_{pbi} = 0.36$

8. The statement, "when a body is wholly or partially immersed in a fluid it appears to lose weight. This apparent loss in weight equals the weight of the fluid displaced", is known as
(a) Boyle's Law
(b) The Principle of Flotation
(c) Charle's Law
(d) Bramah's Principle
*(e) Archimedes' Principle
(Recall) $p = 0.63$ $r_{pbi} = 0.49$

9. Which one of the following statements is FALSE?
(a) increasing a solvent's temperature AND breaking up a solute increases the rate of solution
(b) distilled water is "soft" because it contains no dissolved magnesium or calcium salts
*(c) blue copper sulphate crystals are anhydrous because they contain no water of crystallisation
(d) pure oxygen is used in the oxyacetylene torch since substances burn better in pure oxygen
(e) hydrogen exists in all living matter AND is practically insoluble in water.
(Evaluation) $p = 0.46$ $r_{pbi} = 0.39$

10. If the earth were 113 million miles from the sun instead of 93 million miles then compared to the present situation the
(a) days would be longer
*(b) year would be longer
(c) seasons would be shorter
(d) average temperature would be higher
(e) seasons would be the same length
(Application) $p = 0.51$ $r_{pbi} = 0.49$

11. The diagram below relates to the question



When the block is stood on its face B it will
(a) exert a greater force than when it stands on face C
(b) exert a smaller force than when it stands on face C
(c) exert a greater force than when it stands on face A
*(d) exert an equal force to when it stands on face C
(e) exert a smaller force than when it stands on face A
(Reason Symbolically) $p = 0.41$ $r_{pbi} = 0.31$

12. One characteristic that is universal among adult insects is
(a) membranous wings
(b) short antennae
(c) sucking mouth parts
(d) one pair of wings
*(e) three pairs of legs
(Recall) $p = 0.34$ $r_{pbi} = 0.52$

13. We know that the pull of the earth on a body is six times as great as the pull of the moon on the same body. We also know that the earth pulls on the standard kilogramme with a force of 2.2 lb.wt., or 1,000 gms. wt., or 1 Kgm. wt.
An astronaut weighing 81 kilogramme weight on the surface of the earth will, on the surface of the moon, weigh,
(a) 13.2 lb. wt.
*(b) 13.5 Kgm. wt.
(c) 486.0 Kgm. wt.
(d) 178.2 lb. wt.
(e) 36.8 Kgm. wt.
(Reason Symbolically) $p = 0.47$ $r_{pbi} = 0.36$

14. Two boys were discussing aspects of space travel. John said, "An astronaut would need some copper sulphate crystals to test the atmosphere of Mars for water. The copper sulphate crystals absorb moisture and dissolve in the moisture absorbed". One thing that may be said about John's statement is, it is
(a) correct because copper sulphate is deliquescent
(b) incorrect because hydrated copper sulphate is anhydrous
*(c) incorrect because hydrated copper sulphate is not used to detect water
(d) correct because copper sulphate is not deliquescent
(e) incorrect because anhydrous copper sulphate is deliquescent
(Evaluation) $p = 0.38$ $r_{pbi} = 0.29$

15. Which of the following statements is INCORRECT?
(a) The orbits of the planets about the sun are on different levels or planes.
(b) Photographs of the night sky taken near the North pole show the star trails to be circular.
*(c) Only the light from stars "twinkles".
(d) A "year" on Jupiter is shorter than a "year" on Neptune.
(e) The sun is the closest star to the earth.
(Evaluation) $p = 0.39$ $r_{pbi} = 0.34$

16. Suppose that over a period of time an astronaut who has made a forced landing on a planet records the following observations:
(i) daylight and night on the planet are of equal length
(ii) sunrise occurs once in every 28 hours, and
(iii) the sun rises in the west and sets in the east.
From this information it is most reasonable to conclude that the planet rotates from
(a) west to east once in every 56 hours
(b) east to west once in every 14 hours

(c) west to east once in every 14 hours
*(d) east to west once in every 28 hours
(e) west to east once in every 28 hours
(Application) $p = 0.43$ $r_{pbi} = 0.36$

17. Which of the following would tend to increase most rapidly if all the owls in the locality were killed?
(a) Kookaburras
(b) Lichen
(c) Robins
*(d) Field mice
(e) Wild ducks
(Application) $p = 0.70$ $r_{pbi} = 0.38$

18. Bill and John dented their only table tennis ball during a game. John suggested the ball be placed in hot water as this would remove the dent. His suggestion is
*(a) correct because the air inside the ball would expand considerably
(b) correct because the ball would expand in the hot water
(c) incorrect because heating the ball expands and buckles it
(d) incorrect because pressure and heat of the water will increase the dent
(e) correct because at any temperature the pressure increases with depth in a liquid
(Evaluation) $p = 0.50$ $r_{pbi} = 0.41$

19. A student placed 100 radish seeds in a glass-covered dish on moist blotting paper and placed the dish in the light. Another 100 seeds treated exactly the same way were set beside the first dish and covered with a cardboard box. Of the seeds in the light 94 germinated, and of those kept in the dark only 90 germinated. On the basis of this information, it may correctly be concluded that
(a) light is necessary for seed germination
*(b) germination of radish seeds takes place in either light or darkness
(c) water is necessary for seed germination
(d) darkness is beneficial to seed germination
(e) differences in temperature cause differences in the per cent of germination
(Draw Conclusions) $p = 0.50$ $r_{pbi} = 0.39$

20. A substance that contains atoms of only one type is called
*(a) an element
(b) a molecule
(c) an isotope
(d) a compound
(e) a nucleus
(Recall) $p = 0.67$ $r_{pbi} = 0.41$

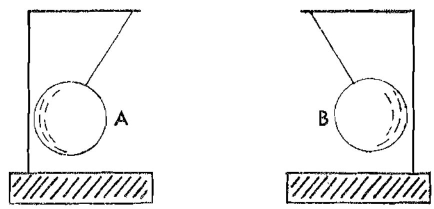
21. The two most abundant elements in the Earth's crust are
(a) oxygen and iron
(b) aluminium and calcium
*(c) silicon and oxygen
(d) hydrogen and oxygen
(e) silicon and aluminium
(Recall) $p = 0.42$ $r_{pbi} = 0.38$

22. The essential material of all living things is
(a) the nucleus
*(b) protoplasm
(c) protozoa
(d) cytoplasm
(e) cellulose
(Recall) $p = 0.48$ $r_{pbi} = 0.35$

23. In which of the following phenomena is the *centripetal* force provided by gravitational attraction?
    (a) dropping a stone inside an aeroplane in flight
    *(b) motion of the moon around the earth
    (c) dropping a stone over a cliff
    (d) whirling a fishing line before casting
    (e) spin drying clothes in a washing machine

(Application) $p = 0.40$ $r_{pbi} = 0.31$

24. Two charged balloons A and B are hung from insulated threads.
    When A and B are brought near one another they are found to repel strongly as shown. From this we may conclude
    (a) A and B possess different types of charge
    (b) the charge on A is negative and the charge on B positive
    *(c) A and B possess similar types of charge



    (d) the charge on A is positive
    (e) the charge on B is negative

(Draw Conclusions) $p = 0.65$ $r_{pbi} = 0.43$

25. When 6 ml of hydrogen are burnt in 12 ml of oxygen then,
    (a) 9 ml of water are formed
    *(b) 3 ml of oxygen are used up
    (c) 3 ml of hydrogen are used up
    (d) 6 ml of oxygen are used up
    (e) 18 ml of water are formed

(Reason Symbolically) $p = 0.31$ $r_{pbi} = 0.29$

26. Greatest competition among plants growing in a forest is caused by the need for
    *(a) light
    (b) water
    (c) space
    (d) minerals
    (e) shade

(Recall) $p = 0.65$ $r_{pbi} = 0.34$

Sub-Test C2

1. On a daily weather map, lines drawn through the locations of the weather stations reporting the same atmospheric pressure for the day are called
    (a) graph lines
    (b) barographs
    (c) isotherms
    (d) thermographs
    *(e) isobars

(Recall) $p = 0.83$ $r_{pbi} = 0.50$

2. The shell of the crab forms an outer skeleton called the
   (a) plate
   *(b) exoskeleton
   (c) cephalothorax
   (d) cheliped
   (e) vertebrate

(Recall) $p = 0.66$ $r_{pbi} = 0.37$

3. The production of large numbers of eggs by certain fish is an adaptation that
   (a) results in the starvation of many of the young
   *(b) increases the chances of survival of the species
   (c) insures an adequate food supply for the young
   (d) enables these fish to exterminate others
   (e) helps insure fertilization

(Evaluation) $p = 0.59$ $r_{pbi} = 0.51$

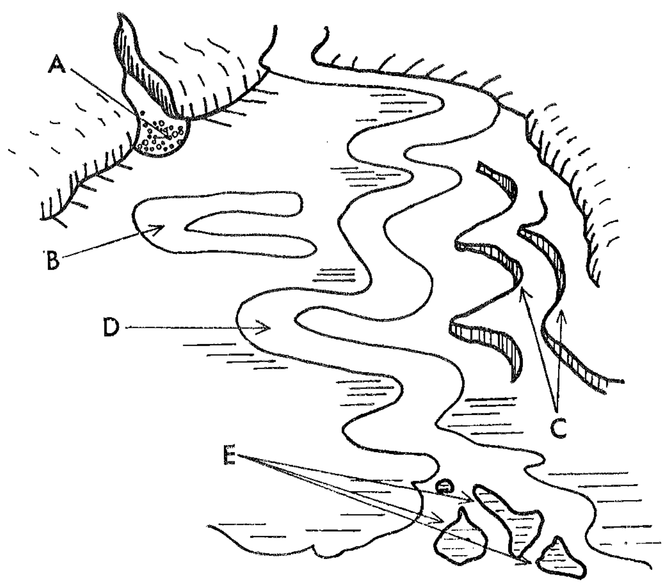
4. Planets differ from stars in that the planets are
   (a) visible because they are incandescent solids
   (b) fixed in space
   (c) visible because they are composed of hot gases
   (d) larger
   *(e) visible because they reflect light

(Recall) $p = 0.55$ $r_{pbi} = 0.41$

5. A molecule of water may be separated into its elements by
   *(a) a direct current of electricity
   (b) evaporation
   (c) a magnetic field
   (d) freezing temperatures
   (e) violent boiling

(Recall) $p = 0.48$ $r_{pbi} = 0.42$

6.



The structures labelled C are called
*(a) river terraces
(b) levees
(c) deltas
(d) moraines
(e) coastal plains
(Recall) $p = 0.69$ $r_{pbi} = 0.36$

7. A scientist predicts that if a planet distant 80 million miles from our Sun possessed an atmosphere of only carbon dioxide (in quantity, less than the present atmosphere on the Earth) weathering of its rocks would occur.
This prediction would most likely be
(a) correct because the main cause of weathering would be chemical action, especially carbonation
(b) incorrect because under these conditions leeching and oxidation could not occur
(c) incorrect because under these conditions frost action could not occur
*(d) correct because under these conditions the main cause of weathering would be due to temperature changes from day to night
(e) correct because under these conditions the main causes of weathering would be carbonation and oxidation
(Evaluation) $p = 0.42$ $r_{pbi} = 0.38$

8. If telephone lines are strung very tightly in the summer
(a) the lines will tend to sag in a day or so
*(b) they will snap in the winter
(c) very little electric current will flow in the lines
(d) very little sound will travel in the lines
(e) they will snap in a heat wave

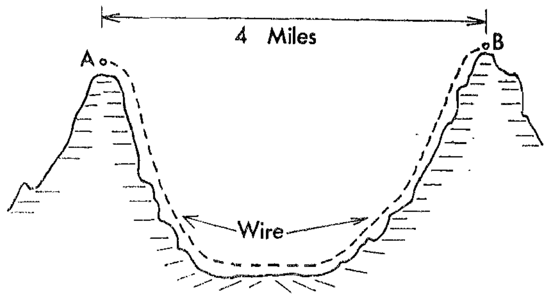
(Application) $p = 0.54$ $r_{pbi} = 0.40$

9. The reason for the answer given in question 8 above is that
(a) the ability to conduct electricity depends upon the tightness of the wires
(b) sound is readily absorbed in metal
(c) the wire in the lines expands in the summer
(d) the weight of the wire causes sagging
*(e) the wire in the lines will contract in the winter
(Evaluation) $p = 0.50$ $r_{pbi} = 0.34$

10. The molecules of matter are in constant motion. In which of the following situations will the molecules be moving the fastest?
(a) ice at 0°C
(b) water at 20°C
(c) water at boiling point
(d) steam at 100°C
*(e) steam at 120°C
(Reason Symbolically) $p = 0.43$ $r_{pbi} = 0.38$

11. Most scientists will agree with four of the following statements concerning evolution. With which of the statements would there be *least* agreement?
(a) Man had ancestors that were not like modern man
(b) Evolution is the racial history of organisms
(c) Evolution is going on today as it did in the past
(d) Man has been on the earth for thousands of years
*(e) Man descended in a direct line from monkeys
(Evaluation) $p = 0.41$ $r_{pbi} = 0.39$

12. Two scientists A and B set up an experiment as follows. They positioned themselves on two hills (see the diagram) about four miles apart and ran two separate lengths of wire, one copper and the other aluminium, above the ground level, as shown.



The wires were specially mounted to insulate them from stray sound waves transmitted through the ground. At a given instant B would simultaneously switch on a light and strike one of the wires with a heavy hammer. When A saw the light he started a stopwatch which he stopped when he detected a sound in a wire. Numerous determinations were carried out using both wires and the scientists found that on the average a sound was heard in the aluminium wire two seconds after A saw the light and in the copper wire, three seconds after A saw the light.

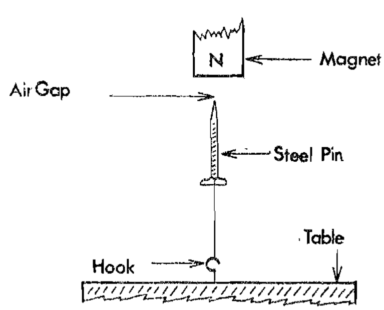
From this experiment we may conclude that
(a) light travels almost instantaneously from B to A
(b) sound travels faster in the copper wire than the aluminium wire
*(c) sound travels faster in the aluminium wire than the copper wire
(d) the speed of sound in the aluminium wire is 2 miles per second
(e) sound travels slower in the aluminium wire than the copper wire

(Draw Conclusions) $p = 0.54$ $r_{pbi} = 0.35$

13. When a gardener transplants a bush or tree, he may cut off some of its leafy branches. What is the scientifically valid reason for this procedure?
(a) it leaves fewer tree parts for parasites to destroy
(b) it enables more sunlight to reach the trunk of the tree
(c) it increases the amount of photosynthesis that will occur
(d) it enables insects to find the blossoms more easily
*(e) it reduces loss of water by evaporation

(Evaluation) $p = 0.39$ $r_{pbi} = 0.42$

14. A steel pin attached to an horizontal table as shown is made to "hang up" by holding a magnet above it as illustrated. Thin sheets of copper, iron, glass and paper which may be placed in the air gap are available.



Select the alternative which you consider makes the statement correct.
Which of the following when placed in the air gap will cause the steel pin to fall?
(a) paper
(b) copper
*(c) iron
(d) glass and paper
(e) copper and paper
(Application) $p = 0.35$ $_{bi} = 0.38$

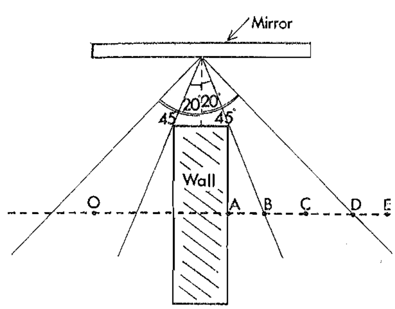
15. Which of these characteristics is probably LEAST determined by heredity in normal human beings?
(a) hair colour
(b) skin colour
(c) blood type
*(d) intelligence
(e) eye colour
(Evaluation) $p = 0.47$ $r_{pbi} = 0.40$

16. Before iron will burn it is essential to
(a) remove any impurities from the iron
(b) add more oxygen to the air
(c) remove any carbon dioxide from the air
(d) remove any nitrogen from the air
*(e) raise the iron to its ignition temperature
(Evaluation) $p = 0.47$ $r_{pbi} = 0.47$

17. The solubility of a substance S in a solvent L at 40°C is 74. This means that the number of grammes of S required to saturate 200 grammes of L at 40°C is
(a) 18.5
(b) 37
(c) 74
*(d) 148
(e) 296
(Reason Symbolically) $p = 0.38$ $r_{pbi} = 0.37$

18. The body temperature of cold-blooded animals is
(a) always lower than that of their surroundings
(b) constant
*(c) nearly the same as that of their surroundings
(d) always lower than that of warm-blooded animals
(e) dependent upon the amount of food they obtain
(Recall) $p = 0.50$ $r_{pbi} = 0.40$

19.



A school boy whose movement is restricted to between A and E wishes to observe what is happening at 0 on the other side of a high wall. A large mirror is positioned as shown. In which of the following positions should he place himself to get the best possible view of 0?

(a) E
(b) D
*(c) C
(d) B
(e) A

(Reason Symbolically) $p = 0.60$ $r_{pbi} = 0.37$

20. In a newspaper article on popular science the writer stated that no force is necessary to keep a car moving with uniform speed on a frictionless straight level road. This statement is

(a) correct because if the force on the car were doubled its speed would double
(b) incorrect because a force would be necessary to maintain the uniform motion of the car
(c) incorrect because Newton's First Law states a force is necessary
(d) incorrect because a force is necessary to overcome the inertia of the car
*(e) correct because a force will only be necessary to change the speed or direction of motion of the car

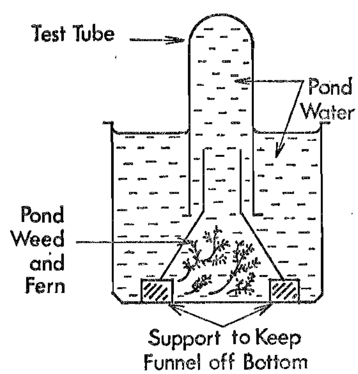
(Evaluation) $p = 0.32$ $r_{pbi} = 0.33$

21. A substance which dissolves in another substance is called

(a) a solvent
*(b) a solute
(c) a solution
(d) a suspension
(e) a distillate

(Recall) $p = 0.48$ $r_{pbi} = 0.39$

22-23. Questions 22 and 23 relate to the diagram below which shows a particular experimental arrangement. The inverted test-tube was initially full of water.



The apparatus was placed in sunlight and bubbles of gas which soon appeared from the cut stems arose and collected in the test-tube. After a time, when sufficient gas had collected the test-tube was removed and a glowing splint inserted. The splint burst into flame.

22. The following conclusion is most consistent with the facts of the experiment

(a) photosynthesis took place
(b) carbon dioxide was liberated during photosynthesis

*(c) oxygen was formed in the process
(d) sunlight is necessary for photosynthesis
(e) oxygen is produced during photosynthesis
(Draw Conclusions) $p = 0.32$ $r = 0.29$

23. If a similar set of apparatus to that shown above were placed in a darkened room and a strong artificial light switched on, we would expect, after a considerable length of time
(a) photosynthesis had not taken place
(b) carbon dioxide to be collected in the test-tube
(c) no gas to be collected in the test-tube
*(d) oxygen to be collected in the test-tube
(e) the plants to be shrivelled up
(Application) $p = 0.32$ $r_{pbi} = 0.28$

24. To produce the effect shown in Diagram 2 below the horizontal strata shown in Diagram 1 would have been subjected to

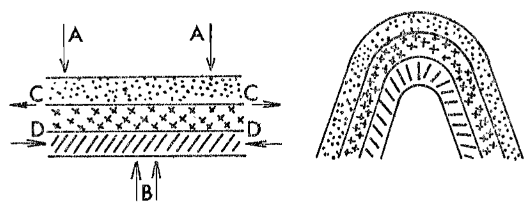
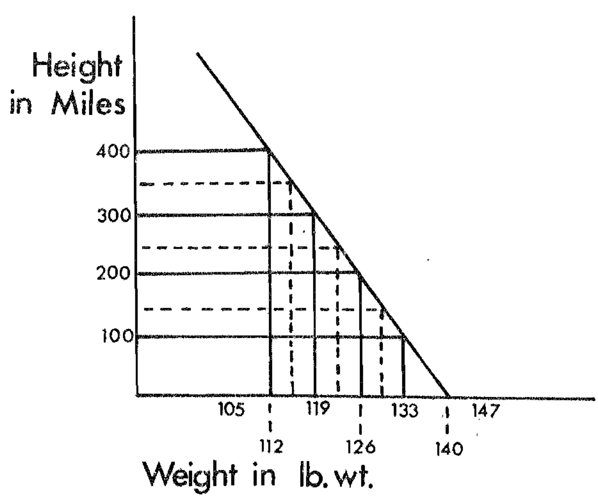


Diagram 1 Diagram 2

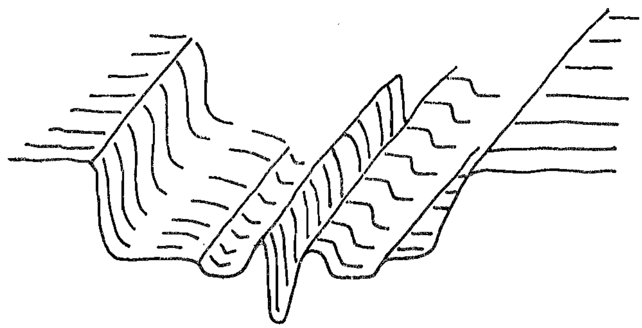
(a) the vertical downward forces A
*(b) the vertical upward forces B
(c) the tension forces C
(d) the compressive forces D
(e) both the tension forces C and the compressive forces D
(Application) $p = 0.47$ $r_{pbi} = 0.35$

25. The graph below shows the results of an experiment in which an object was weighed at various heights above sea level



In the light of the above results which one of the following conclusions do you consider to be correct?
(a) when the object weighs 128 lb. wt. it would be at a height of 125 miles
(b) when the object has ascended to 300 miles its weight has increased by 119 lb.wt.
*(c) for every 100 miles ascended there is a decrease of 7 lb.wt. in the pull on the object
(d) for every 100 miles descended there is a decrease of 7 lb.wt. in the pull on the object
(e) at heights below sea level the weight of the object is 140 lb.wt.
(Reason Symbolically) $p = 0.39$ $r_{pbi} = 0.37$

26. In a certain region a geologist notes a valley has the form sketched in the diagram below.



It is most reasonable for him to conclude that the valley was formed by
(a) glacial erosion
(b) recurring floods
(c) action of rivers followed by glacial erosion
(d) action of rivers
*(e) glacial erosion followed by action of rivers
(Application) $p = 0.39$ $r_{pbi} = 0.34$

Sub-Test C3

1. What substance is found in every living cell?
(a) chlorophyll
(b) cellulose
*(c) protoplasm
(d) starch
(e) cytoplasm
(Recall) $p = 0.73$ $r_{pbi} = 0.42$

2. Two boys gently heating a test-tube of water noticed small bubbles forming in the water long before the water boiled. One boy said they were bubbles of gas. Now select the statement below with which you agree.
The boy's remark is
(a) incorrect because the solubility of oxygen is very low
(b) correct because increasing the temperature of water decreases its solubility
(c) incorrect because decreasing the temperature of water decreases its solubility
*(d) correct because small quantities of air do dissolve in water
(e) incorrect because steam bubbles form as the temperature increases
(Evaluation) $p = 0.50$ $r_{pbi} = 0.41$

3. Which of the following gases makes up a higher percentage of the atmosphere around industrial cities than in rural areas?
   (a) Oxygen
   (b) Helium
   (c) Nitrogen
   (d) Argon
   *(e) Carbon dioxide

(Recall) $p = 0.57$ $r_{pbi} = 0.38$

4. A translucent body is one which
   *(a) allows some light to pass through
   (b) allows no light to pass through
   (c) glows under artificial light
   (d) appears coloured in a darkened room
   (e) allows all light to pass through

(Recall) $p = 0.59$ $r_{pbi} = 0.58$

5. A hiker comments to his companion that all the wide streams they have crossed are more powerful eroding agents than the narrower faster flowing streams. This statement must be regarded as
   (a) incorrect because erosive power depends on the quantity and nature of the matter carried in solution by the streams
   (b) correct because erosive power is dependent on the velocity of a stream
   (c) incorrect because erosive power is dependent mainly on the nature of the materials carried in suspension by a stream
   *(d) incorrect because both stream velocity and volume of water in a stream affect its erosive power
   (e) correct because erosive power decreases with an increase of volume of water in a stream

(Evaluation) $p = 0.48$ $r_{pbi} = 0.36$

6. For a particular element the number of protons in the nucleus of an atom of that element is known as its
   (a) atomic weight
   (b) valency
   (c) electron number
   (d) isotope
   *(e) atomic number

(Recall) $p = 0.55$ $r_{pbi} = 0.35$

7. The closest star to the earth is
   (a) Betelegeuse
   (b) Alpha Centauri
   *(c) The Sun
   (d) Sirius
   (e) Venus

(Recall) $p = 0.46$ $r_{pbi} = 0.35$

8. A sensitive barometer reads 29.46 inches in a classroom. The reading will be slightly higher if the barometer is placed
   (a) in a room on the same floor, where the humidity is very high
   (b) outside the window on the same level, where the temperature is lower
   (c) on the roof of the building above the classroom
   (d) under a bell jar attached to a vacuum pump
   *(e) on the floor of the basement under the classroom

(Application) $p = 0.36$ $r_{pbi} = 0.38$

9. A block of wood which weighs 40 gm.wt. and has a volume of 50 ccs. is carefully placed in a dish filled to the brim with water. How much water will spill out if the block floats?
   (a) 50 ccs. of water
   (b) 10 gms.wt. of water
   (c) 90 gms.wt. of water
   (d) more than 50 ccs. of water
   *(e) 40 gms.wt. of water

(Reason Symbolically) $p = 0.34$ $r_{pbi} = 0.32$

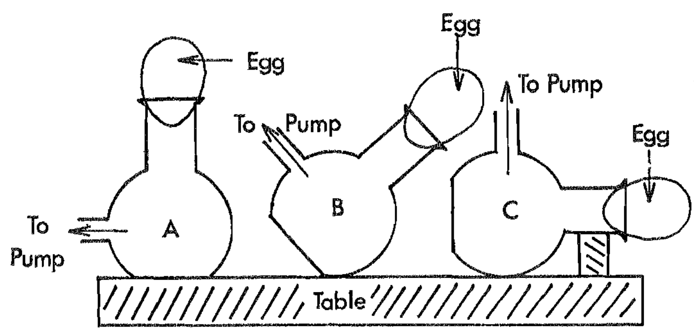
10. In an organism the process of cell division which results in the daughter cells possessing the same number of chromosomes as the parent cell is called
   (a) meiosis
   (b) symbiosis
   *(c) mitosis
   (d) genetic continuity
   (e) metamorphic

(Recall) $p = 0.61$ $r_{pbi} = 0.29$

11. Assume that it is possible to replace the plasma membrane of a living cell with some thin plastic similar to that used to package goods. If this were done the cell would
   (a) be unaffected by the change
   (b) decrease in size because nothing could leave it
   (c) readily adapt to the change
   (d) increase in size because nothing could leave it
   *(e) die because the cell contents could not be regulated

(Application) $p = 0.59$ $r_{pbi} = 0.33$

12. Three hard boiled eggs with their shells removed are placed in the mouths of three identical vessels as shown. Each vessel is connected to a vacuum pump.



When the air is evacuated from each flask,
   (a) the eggs will be forced into flask B only
   (b) the eggs will be forced into flasks A and B only
   (c) the eggs will be forced into flasks A and C only
   *(d) the eggs will be forced into flasks A, B and C
   (e) the eggs will be forced into neither flask A, nor B, nor C

(Application) $p = 0.45$ $r_{pbi} = 0.34$

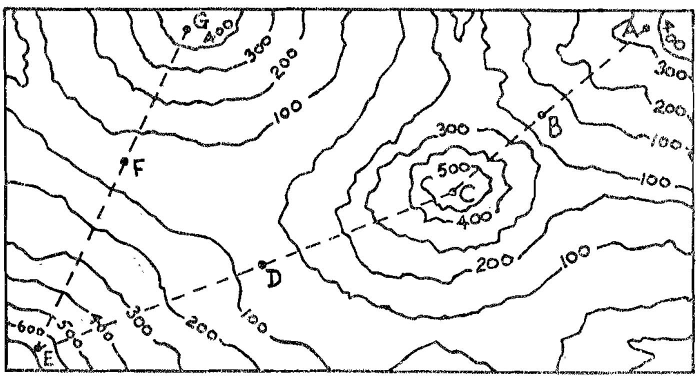
13. When an animal hibernates, or a plant goes into a dormant state, which one of the following conditions exists?
   (a) there is no life present in any of the animal or plant cells

(b) the animal or plant is absorbing additional energy for use during periods of active life
*(c) the animal or plant is using less energy than during the periods of active life
(d) the temperature of the animal or plant is usually higher than it is during periods of active life
(e) the animal or plant becomes more responsive to outside influences than it normally is
(Evaluation) $p = 0.48$ $r_{pbi} = 0.32$

14. If an atom has 9 protons and 11 neutrons then the number of planetary electrons is
(a) 20
*(b) 9
(c) 11
(d) 2
(e) 1
(Reason Symbolically) $p = 0.46$ $r_{pbi} = 0.35$

15. The following five answers were given in reply to the question "Why is water that is pumped from a deep well usually harder than water taken from a shallow well?" Select the reply you consider gives the best correct answer.
(a) water pumped from a deep well has to travel through a longer pipe
(b) water at great depths contains more dissolved air
(c) there is more carbon dioxide in both air and water at greater depths
*(d) water at great depths contains more dissolved mineral matter
(e) water pumped from a deep well is denser because of the greater pressure at greater depths
(Evaluation) $p = 0.56$ $r_{pbi} = 0.36$

16. The diagram below represents a contour map of a given region.



From the statements which follow select the one which is *incorrect.*
(a) A hiker travelling from A to C and another travelling from G to E both increase their height above sea level by the same amount
*(b) C is the highest point in the region
(c) A walk from A to E would involve traversing two valleys
(d) Hills in the region would occur at C, E and G
(e) Valleys in the region would occur at B, D and F
(Reason Symbolically) $p = 0.48$ $r_{pbi} = 0.35$

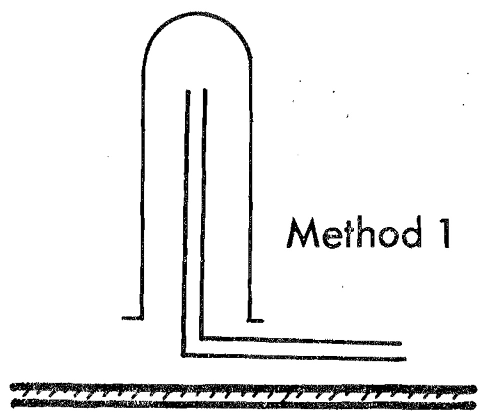
17. Although coral does not flourish at depths of greater than 300 feet a bore sunk on

an island passed through coral for over 700 feet. This provides evidence of past
(a) volcanic activity
(b) folding
(c) earthquakes
(d) faulting
*(e) subsidence
(Application) $p = 0.44$ $r_{pbi} = 0.42$

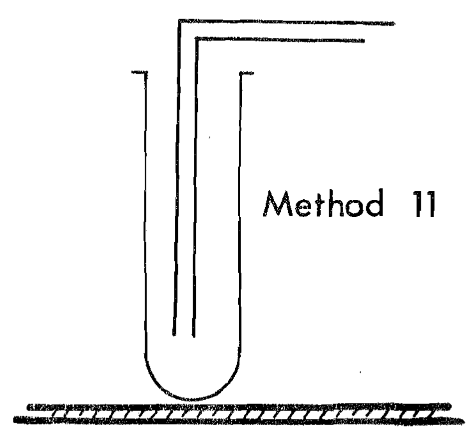
18. Which of the following statements is *incorrect*?
(a) Doubling the rate of flow of a stream may result in an increase in its carrying capacity by as much as 30 times
(b) Most earthquakes start from faults 40 miles or less below the earth's surface
(c) Heat for igneous activity such as volcanic activity most probably comes from radioactivity and chemical reactions in the earth's crust
*(d) In the lowest plain country in a river's course there is usually excessive river erosion
(e) Some earthquakes may occur at depths of 400 miles below the earth's surface
(Evaluation) $p = 0.39$ $r_{pbi} = 0.41$

19-21. Questions 19, 20 and 21 are related to the details below.
A gas of unknown chemical and physical properties is provided and its collection is attempted in the laboratory in the three ways illustrated in the diagrams below.

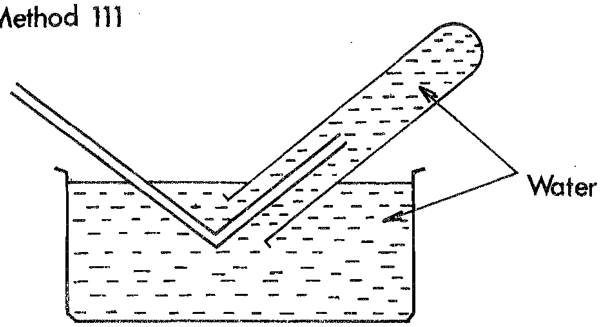
Method I The gas is passed in to the test-tube, as shown, for several minutes. The delivery tube is removed and with the test-tube in the same position a burning taper is introduced into the tube. The taper burns briefly, then goes out.



Method II The gas is passed into the test-tube as shown, for several minutes. The delivery tube is removed and with the test-tube in the same position a burning taper is introduced into the tube. The taper is immediately extinguished.



Method 111



Method III The gas is passed, as shown, for several minutes, but no change is noted in the water level of the test-tube.

Now attempt questions 19, 20 and 21.

19. From the above results we may conclude or state that
 (a) the gas is less dense than oxygen
 (b) the gas is less dense than hydrogen
 (c) we have insufficient evidence to judge the density of the gas compared to other gases
 *(d) the gas is more dense than air
 (e) the gas is more dense than hydrogen but less dense than air

(Draw Conclusions) $p = 0.34$ $r_{pbi} = 0.35$

20. We may also conclude or state that
 (a) the gas will burn
 (b) the gas supports combustion
 (c) the gas is explosive
 *(d) the gas does not support combustion
 (e) we have insufficient evidence to judge about the combustion of the gas

(Draw Conclusions) $p = 0.42$ $r_{pbi} = 0.30$

21. With respect to the behaviour of the gas with water we can conclude, the gas
 *(a) dissolves and may react chemically with water
 (b) is insoluble in water
 (c) reacts chemically with water
 (d) does not react chemically with water
 (e) is soluble in water but does not react with it

(Draw Conclusions) $p = 0.34$ $r_{pbi} = 0.31$

22. Which one of the following is *not* a chemical change?
 (a) the fading of coloured cloth
 (b) the burning of magnesium ribbon
 (c) the corroding of a copper roof
 *(d) the dissolving of sugar in water
 (e) the explosion of petrol

(Application) $p = 0.32$ $r_{pbi} = 0.30$

23. It can be said of the two isotopes Cl^{35}_{37} and Cl^{37}_{17} that they differ in
 (a) all chemical properties
 *(b) weight
 (c) some chemical properties
 (d) number of electrons
 (e) number of protons

(Recall) $p = 0.39$ $r_{pbi} = 0.34$

24. Which one of the following animals can most easily change his surroundings to fit his needs?
    (a) a whale
    (b) a gorilla
    *(c) a man
    (d) an elephant
    (e) a horse

(Evaluation) $p = 0.50$ $r_{pbi} = 0.38$

25. The instrument in which a small current is produced in two dissimilar wires when heat is applied to one of the junctions between the wires is called a
    (a) thermopile
    (b) photometer
    (c) galvanometer
    *(d) thermocouple
    (e) solar cell

(Recall) $p = 0.31$ $r_{pbi} = 0.39$

26. Using a specialized technique it is possible to remove the nucleus from a cell without severely damaging the cell wall. If this were done we would then find that the cytoplasm would
    (a) manufacture a new nucleus
    (b) move about wildly
    (c) split into two to form two new cells
    *(d) gradually cease functioning
    (e) function normally

(Evaluation) $p = 0.46$ $r_{pbi} = 0.40$

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