A COMPARISON OF TWO METHODS IN THE TEACHING OF PHYSICS

by

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ABSTRACT

The purpose of this study was to compare two methods of teaching science. The two methods were a self-paced method which used learning activity packages stated in behavioral objectives and a teacher-paced, teacher-directed method in which the students were not given the objectives.

This investigation was undertaken because the effectiveness of the self-paced method had been questioned in the school situation where it was being applied. The existing situation at the initiation of this study at Frank Hurt Secondary in Surrey, British Columbia, provided the setting for a natural experiment.

The experimental phase of this study took place over the first two trimesters of the school year. The subjects were students in four science eight classes. Two classes were taught by each of the two teachers, with one class, for each teacher, randomly assigned to each method.

The effectiveness of the teaching methods was determined by comparing the mean scores of the five dependent variables: acquisition and retention of science knowledge, understanding of science processes, and students' attitudes to experimenting and independent investigations. The data were analyzed using a two by two by two (method-by-teacher-by-gender) fixed effects factorial design.

The results of the analyses indicated that the self-paced method was as effective as the teacher-paced method as measured on four of the dependent variables and was superior to the teacher-paced method for teaching and understanding of science processes. A significant interaction effect between the teaching method and the gender of the student showed that males scored much higher on the Test of Science Processes when taught by the self-paced method. Contrary to what was expected the gender of the student was found to have no effect on student achievement or attitudes to science. Significant interaction effects between teacher and teaching method for the two attitude scales indicated that the effectiveness that a teaching method had on student attitudes depended on the teacher using the teaching method.

Recommendations for further research were proposed. Finally, the epilogue brings the reader up to date on the use of the self-paced method of teaching at Frank Hurt Secondary.

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CHAPTER 1

INTRODUCTION

1.0 The Problem

The purpose of this study was to compare two methods of teaching science. The study was undertaken because the effectiveness of one method, the use of a self-paced program using learning activity packages stated in behavioural terms, had been questioned in the school situation where it was being applied.

After several years of operating on this system it was becoming apparent that there were effects being produced that were deemed undesirable. The procedure of setting the course out in learning activity packages clearly specified to student and teacher alike what had to be accomplished. If students did not complete all of the work for a course in one year it was carried over into the next year. This meant that they had more work to do the following year in order to keep up the expected rate of progress. The number of students that were incomplete appeared to be growing. This led to concern on the part of the administration for these students. A survey of student progress was initiated at this point. The survey showed that about 20 percent of the students failed to complete a particular course that was offered. About one half

of these students were less than three quarters of the way through the incomplete course. Approximately one third of the students were behind in at least one course. For the less capable student it meant that the longer they stayed in this system the farther behind they were likely to become. There were of course many exceptions to this. A number of students were able to complete two years work within one school year in a particular subject. This system allowed them to broaden their course selections and take courses they otherwise would not be able to take due to limitations in the timetable. Several students were able to use their time to enroll in Douglas College. Fortunately it is located about two miles from the school so they could commute to college during the school day.

The major effect that this system produced was that it showed up every discrepancy between a student's progress and the expected rate of progress. Students were held accountable to make up this incomplete work. This led, in many instances, to an accumulation of incomplete work.

It was felt that a more commonly implemented method, teacher-directed and teacher-paced would be more effective. However, a more conventional teaching method is likely to produce similar variations in students achievement, as does the self-paced method, but many of the discrepancies between course outline and student achievement are not detected due to the reporting system. It appears that the conventional

teaching method is more successful if only course completion is looked at, but it should be remembered that in a conventional system some students complete the course but are given a lower grade because some parts of the course have not been completed satisfactorily.

This led to the conditions for a natural experiment at Frank Hurt Secondary School. Thus, this study was an attempt to determine, in the school in question, whether the present self-paced program was as effective as the more conventional method for teaching science.

1.1 Importance of the Problem

Frank Hurt Secondary School was set up as an alternate school. The teaching method used throughout the school was one that allowed students to work at their own pace, thereby accommodating different individual learning rates.

In order to facilitate students working at their own pace, learning activity packages were developed. These packages were stated with behavioural objectives so that the students would know what was expected of them and to direct the students' efforts towards a goal. The students were also provided with written instructions informing them about which books and materials to use when doing the work. The teacher's role was that of designer of packages, consultant to the students about their work, and evaluator of their progress. The setting up of this school as an alternate school was part of a trend in

education to provide alternate forms of educational practice designed to meet individual differences among students.

Although the program had been used in the school for three years, there were pressures to change the teaching method and return to a more conventional - teacher-directed and paced - method of teaching. The question needed to be asked as to whether or not the teaching methods used to allow for differences in learning rates are as effective for the student population as a whole as are the more conventional teacher-directed and paced methods. In attempting to determine the comparative effectiveness of this alternate method of teaching some light may also be shed on problems that are encountered when attempts to implement new programs are made.

1.2 The Specific Problem

The comparison of these two methods was done on the basis of what effect they had on five dependent variables: achievement in science, retention of science knowledge, understanding of science processes, student attitude to experimenting, and to investigating independently.

The effect that the sex of the student had on the five dependent variables was also investigated. The sex of the student is generally thought to have an effect on achievement in science and therefore attitudes to science.

Thus, these comparisons involving treatment and sex can be put in the form of questions. The main questions were

those concerning the comparison of teaching methods. The other questions were those involving the sex of the student and the interaction effects between teaching methods and the sex of the student.

The main question:

1. Do Grade eight students taught using a self-paced program perform as well as Grade eight students taught using a teacher directed-teacher based program in terms of acquisition and retention of science knowledge, understanding of science processes, attitudes to experimenting, and independent investigations?

The two subsidiary questions:

2. Do male Grade eight students perform as well as female Grade eight students in terms of acquisition and retention of science knowledge, understanding of science processes, attitudes to experimenting and independent investigations?

3. For Grade eight students do interactions between the teaching method and the sex of the student affect student performance in terms of acquisition and retention of science knowledge, understanding of science processes, student attitudes to experimenting and independent investigations?

Definition of Terms

Attitude - an enduring organization of motivational, emotional, perceptual, and cognitive processes with respect to some

aspect of the individual's world (Krech, Crutchfield, and Ballachey, 1962, p. 152).

Self-paced learning - students are given a more-or-less set curriculum, but have some flexibility in determining how fast they will move through the materials.

Experimental teaching method - for the purposes of this study is the teaching method that uses student self-paced learning and learning activity packages with behavioural objectives.

Conventional teaching method - for the purposes of this study is the teaching method that uses teacher direction, teacher pacing, and implied rather than explict objectives.

Science processes - the procedures followed by an investigator during scientific enquiry. For example, observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting (Tannenbaum, 1971).

Learning activity packages (LAP's) - units of work on a topic that are sequential and indicate the source of each activity. An example of a LAP is given in Appendix D.

Behavioural objectives - objectives that specify an observable student outcome.

1.3 Hypotheses

Because previous studies, taken together, do not provide definitive results regarding the differential effect of a self-paced learning program in comparison to a teacher-paced program the research hypotheses were stated in the null form.

Each of the hypotheses was tested for each of the following dependent variables:

a) achievement in science

b) retention of science knowledge

c) understanding of science processes

d) students' attitude to experimenting

e) students' attitude to independent investigation.

The three hypotheses, corresponding to the three earlier stated research questions, were:

1. There is no difference in mean performance on each of the dependent variables between Grade eight students taught by a self-paced method and Grade eight students taught by a teacher-directed, teacher-paced method.

2. There is no difference in mean performance on each of the dependent variables between males in Grade eight and females in Grade eight.

3. There are no significant interactions between teaching method and sex of the student, as measured by the mean performance of Grade eight students on each of the five dependent variables.

The .05 level for statistical significance was used to test each hypothesis separately. Missing data precluded the use of multivariate procedures. Further, since the study was somewhat more exploratory than definitive, a more relaxed level of α was selected, thereby providing somewhat more power to detect possible differences.

CHAPTER 2

REVIEW OF THE LITERATURE

2.0 Self-Pacing

The desire to provide for individual differences in student abilities and interests has led to the introduction of many individualized programs. Although many of these programs are not truly individualized, several do utilize the self-paced mode of learning. "A truly individualized method would also have alternative learning sequences and alternative modes of reinforcement" (Burns, 1971). In practise the self-paced mode is emphasized and whole-class instruction is de-emphasized.

Achievement

In ten of only twelve cases found in the literature, students who used a self-paced program of study did as well or better than students that were in teacher-paced classes. Significant increases in students' achievement were reported by Steele (1974), Siemankowski (1969), and Fulton (1971) for students in self-paced classes.

Steele (1974) did a comparative study of self-paced and lecture-discussion methods in university physics for non-science majors. He found there was a positive significant difference in students' achievement in favour of the self-paced program. Siemankowski (1969) likewise conducted a study of university physical science students using a self-paced program

and found a significant positive gain in achievement when compared to conventional methods of teaching. Fulton (1971) conducted his study with high school students studying the BSCS course and also found significant increases in achievement with the self-paced mode as compared to the teacher-paced mode.

The self-paced method was as effective as the teacher-paced method in improving student achievement as shown in studies done by O'Toole (1968), Kline (1971), Ketchum (1972), Cise (1978), Anderson (1980), James (1972), and Nieft (1973). The subjects in these studies range from elementary school to university students.

Cise (1978) did a study on college physics students using a self-paced program and found no significant difference in achievement between this mode of learning and the teacher-paced mode. Kline (1971) and Ketchum (1972) did studies involving eighth and ninth grade students respectively. Both studies compared self-paced to teacher-paced programs and neither found any significant difference in science achievement between the two groups of students. The other studies were done with elementary school science students and showed no significant difference in science achievement between the self-paced and teacher-paced mode of teaching.

The study by Richter (1972) is the only study reviewed that shows a positive difference in favour of the teacher-paced method. His study involved teaching units in heat and sound to students in a post secondary vocational institution. The laboratory experiences of these units were either self-paced or

teacher-paced. The teacher-paced group showed significantly greater gains in achievement than the self-paced group. Roberson and Crowe (1975), teaching topics in fluid mechanics to engineering students, indicate that the self-paced group scored four to six percent less on achievement tests than the teacher-paced group but do not indicate in their study if this difference is significant.

Attitude

The studies of student attitudes to self-pacing and science show mixed results similar to the studies of student achievement. Steele (1974), Fulton (1971), James (1972), and Siemankowski (1969) all indicate that students who have experienced self-pacing prefer it to conventional teacher-pacing. All found that students had a positive attitude to this mode of learning and wanted to continue with it in future courses. However, several studies (Roberson, 1975 and Reed, 1974) report negative attitudes to self-pacing and a preference, on the part of students, for teacher-pacing. These studies were done on diverse groups - Roberson with engineering students and Reed with Grade seven students. It seems unlikely that their negative attitude is a function of maturation.

The literature indicates that self-pacing is as effective or more effective in forming students' attitudes to science. Steele (1974) and Siemankowski (1969) both report more positive attitudes to science when the self-paced mode is used. No difference in attitude to science is shown in studies by O'Toole (1968), Nieft (1973), Kline (1971), and Anderson (1980).

No studies reviewed showed a decline in the attitude of students toward science when the self-paced mode was used. The self-paced mode appears to be as good as or better than the teacher-paced mode in developing attitudes toward science.

The self-paced mode generated more positive attitudes toward the teacher in two of the studies reviewed, Ketchum (1972) and Fulton (1971). Fulton (1971) reported that students perceived the teacher as being more able to make the material understandable when the self-paced mode was used. Ketchum (1972), reported that students using the self-paced mode "showed greater positive attitude change in the perception of teacher characteristics, specifically in the areas of enthusiasm, ability to elicit student understanding, and the ability to develop trust." (p. 2195)

2.1 Learning Activity Packages

One procedure that has been used to individualize instruction has been the use of learning activity packages (LAP's). The nature of these packages has varied from simple programmed instruction units to elaborate packages containing a rationale, specific performance objectives, provisions for self assessment, options for depth study, and definite teacher evaluation. An attempt has been made to review only those studies which have LAP's similar to those defined in Chapter One. The effects that the use of learning activity packages have on learner outcomes are often lost because LAP's are associated with other instructional procedures such as self-pacing.

Increases in science achievement were shown by six of the studies reviewed:-Flowers (1977), Glasser (1976), Hedges (1964), Moriber (1967), Steele (1974), and Sayles (1966). All of these studies used LAP's in some form. Glasser (1976), compared the effectiveness of LAP's to conventional methods for teaching fifth grade science. She found that the LAP group scored higher on achievement and the difference between groups was statistically significant at the .0001 level. Steele (1974), compared the LAP method to the lecture-demonstration method of instruction for college students enrolled in a physics course for non-science majors. There was a significant difference in student achievement between the two groups in favour of the LAP group. Moriber (1967) and Sayles (1966), both used short time duration programmed packages to teach specific units of college physical science and high school chemistry respectively. Both found that significant gains in achievement were made using this method. Moriber (1967) also found that the LAP method was superior to a conventional lecture-demonstration method for teaching a college physical science course. The difference in student achievement was significant at the .01 level.

Flowers (1977), compared learning activity package instruction to teacher centered instruction for science eight students and found that the learning activity package group had higher achievement in science although the increase in achievement was not significant at the .05 level.

Hedges (1964) reported increases in achievement of fourth grade students using LAP's. Many other studies (Anderson, 1980, Barnes, 1969, Boudreaux, 1970, O'Toole, 1968, and Zeschle, 1966) have shown that groups using LAP's achieve at the same level as students taught in the more conventional teacher centered class. No studies reviewed reported decreases in science achievement when LAP's were used. So, it appears from the literature that the use of LAP's is as or more successful than the conventional teacher centered method of teaching science.

Students that have used the LAP's have been positive in their attitudes to their use. Anderson (1980), Barnes (1969), Hedges (1964), Moriber (1967), Steele (1974), and Zeschle (1966) all report that students who have used LAP's have a positive attitude to this method of instruction. Barnes (1969) and Steele (1974) both found that students preferred the LAP method over the conventional teaching method. The other four studies found that students using LAP's were strongly in favour of their use. Barnes (1969) found 75% of the students in a university freshman physics course preferred using LAP's rather than a conventional teaching method. Steele (1974) found the same preference for LAP's amongst the college physics students in his study. Boudreaux' (1975) study is the only one reviewed that showed no significant difference in the attitudes of students between LAP's and a conventional teaching method. Her study was done with grade nine earth science students. As well as the attitude of students to LAP's their attitudes to science were also reported

in several studies. Hedges (1964) found a significant difference in attitude to science when LAP's were used, "The student's attitudes toward science are extremely positive. In fact they are enthuasiastic." (p. 69) Whereas, Anderson (1980) and O'Toole (1968) found no significant difference in the attitudes of students to science using either method.

Only one study reported the effect of LAP's on retention of science knowledge. Moriber (1967) found no significant difference in retention between students using LAP's and being taught by the conventional method in a college physics course. As far as the research of the effects of LAP's differentiating the attitudes of boys and girls toward science, Anderson (1980) reports finding no difference that is attributable to the teaching method used.

The interaction between either teaching method and the sex of the student with regard to achievement in science is not definitively determined in the literature. Anderson (1980) and Glasser (1976) found that the use of LAP's did not favour either sex. This result as Glasser (1976) points out "is a finding contrary to certain studies found in the literature. The conclusion is that boys and girls achieve in science to a similar degree." (p. 4096) The expected result was that boys would do better in science. The findings of Campbell (1972) and Najmaie (1974) are contrary to those of Anderson (1980) and Glasser (1976). Campbell (1972) found that "girls are found to be more successful than boys in using LAP's." (p. 117) Najmaie (1979) found that female college students who had used LAP's in one

biology course "had significantly better long-term achievement results in subsequent life-science courses." (p. 5812) The issue of how the use of LAP's interacts with the gender of the student is not clear in the literature. However, it should be noted that Campbell (1972) strongly suggests that the use of LAP's for individualizing for all students may not be appropriate.

2.2 Behavioural Objectives

The effect that the use of behavioural objectives has on learning outcomes has not been clearly determined. The literature on the effect that providing students with behavioural objectives has on achievement shows results that are inconsistent. Little research has been done to determine the effect that providing students with behavioural objectives has on student attitudes or retention of knowledge.

Achievement

Many studies investigated the effect that prior knowledge of behavioural objectives has on student achievement. The results of these studies are evenly divided between those that reported increases in achievement when behavioural objectives were used and those that found no effect caused by prior knowledge of behavioural objectives. No studies indicated a decrease in achievement when behavioural objectives were provided. Olsen (1973), reported significant differences in achievement of grade nine physical science students when classes of students that had been given behavioural objectives were compared with classes that

had not received them. The difference in achievement was statistically significant at the .01 level. Anderson (1975) and Edmondson (1978) both found increases in achievement when behavioural objectives were given to the students prior to the learning sequence. Anderson's (1975) study involved university students in an elementary science methods course and Edmondson's (1978) study was done with pharmacy students. Edmondson (1978) found that student's knowledge was significantly increased when behavioural objectives were used. The difference in knowledge between the group using the behavioural objectives and those using no objectives was significant at the .05 level.

In a study done with grade ten health students, Dalis (1970) compared the achievement of students who had precise objectives, vague objectives, and no objectives. She found that the group with precise objectives had much higher achievement scores on a 68 item multiple choice test than the other students in the study. The differences in achievement were statistically significant at the .01 level.

Akers (1979) and Hass (1977) also found achievement was increased when behavioural objectives were given to the students. However, neither study presents a clear cut increase in achievement. Akers (1979) found that in only one of the four units presented to eighth grade students was there a significant difference between the achievement of the experimental group that received behavioural objectives and the control group that did not. Hass (1977) found that college biology students who had

been given behavioural objectives prior to the course had significantly increased achievement as measured by a teacher made test but that there was no increase in general biology achievement as measured by the Nelson Biology test.

Herron (1971) found that students rated by their SAT scores as being of lower ability did consistently better when they were given behavioural objectives. Although on only one of three tests was the difference between the groups statistically significant. However, on all three tests the group that had been given behavioural objectives received higher scores on an achievement test.

Boardman (1970) and Conlon (1970) both found that achievement scores were improved by presenting behavioural objectives to the students but in neither case was the increase statistically significant. Although Boardman (1970) did not find any statistically significant difference in achievement scores she did find that in the group that received behavioural objectives the letter grade mode rose from 2.0 (C) to 3.0 (B) and that no such increase was found in the control group.

Anderson (1980), Bryant (1972), Bishop (1969), and Coleman (1972) all found no significant difference in achievement scores between groups of students that received behavioural objectives and those who did not.

There seems to be little differentiation by sex on science achievement when behavioural objectives are used. Anderson (1980) and Colemen (1972) could find no significant difference

in science by either males or females. Akers (1979) did find that boys scored slightly higher than girls in a ninth grade physical science course when behavioural objectives were given to both groups and that girls who were given objectives did slightly better than girls who were not given them. Neither of these results were statistically significant.

Where achievement in science is concerned there could be an interaction between intelligence and the receiving of behavioural objectives. Conlon (1970) and Hass (1977) found there to be no difference in achievement by ability groups. Johnson (1975) found that when teaching high ability students it makes no difference whether or not they have received behavioural objectives. With lower ability groups, the group that received behavioural objectives did better than the group that did not receive them. Bryant (1972) and Herron (1972) also had similar results with low ability groups.

Very little has been reported about the effects of behavioural objectives on retention of knowledge. Olsen (1973) and Bishop (1969) did studies of the effects of behavioural objectives on retention. The measures for retention in both studies were given a relatively short time after the treatment was concluded - three weeks in Olsen's (1973) study and thirty days in Bishop's (1969) study. Olsen (1973) found that there was a significant difference in retention between the experimental and control groups - the group that received the behavioural objectives did much better. Bishop (1969) found no significant difference in retention between the two groups.

It might be expected that the use of behavioural objectives would improve student attitudes to science. If, as Engle (1970) says, the use of behavioural objectives allows the student to know what is expected of him and to also know how he is progressing, then an improved attitude should follow. Anderson (1980), Coleman (1972), and Hass (1977) found there was no difference in the attitudes of students that received behavioural objectives and those who did not receive them.

When teachers rather than students are given the behavioural objectives, there are similar mixed results. Bryant (1972) found that there was a significant increase in cognitive achievement of students taught by teachers that used behavioural objectives and those that did not use them. Herron (1971) suggests that the slight differences he found in student's achievement when they were given behavioural objectives, may have been due to the fact that the teachers of this group also were given the same objectives. Nieft (1972) expected to find a change in student attitudes when teachers were given a list of behavioural objectives for the ISCS level 1 course but, found instead that there were no differences between the attitudes of ISCS students whose teachers had the behavioural objectives and non-ISCS students whose teachers had not been given objectives. Baker (1969), in a study done with 18 teachers in Nevada high schools, found that even when teachers had been given the behavioural objectives to teach to their classes they were unable to correctly identify, beyond at chance level, test questions appropriate to these objectives. A questionnaire revealed that teachers used only 29

percent of their instructional time in activities relevant to the behavioural objectives they had been given and only 28 percent of the activities they used were judged to be relevant to the behavioural objectives.

Boardman (1970) found that when students worked on an individualized packaged system they found the packages of help only when they included behavioural objectives. Boardman (1970) stated, "There was a definite indication that students need instructions in the use of behavioural objectives" and "more than printed instruction."

Summary

The literature reviewed has not provided definitive answers regarding the effects that the use of self-pacing, learning activity packages or behavioural objectives have on the acquisition and retention of science knowledge or students' attitudes to science. The experimental teaching method used in this study was characterized by the use of all three of these attributes. Therefore, there is a need to determine what effects self-pacing, learning activity packages, and the use of behavioural objectives have on the acquisition and retention of science knowledge and on students' attitudes to science. None of the studies reviewed indicated what effect these characteristics of the experimental method had on learning science process skills and few dealt with the question of the retention of science knowledge. Thus there is a need for a study to determine what effects these characteristics have on the acquisition and retention of science knowledge and students' attitudes to science.

2.3 Context of the Study

In order to put this study into the larger perspective of what has taken place at Frank Hurt an attempt will be made to document the major changes and to more fully describe the school as it was when first opened.

The self-paced method was initiated as a means of providing for differences among students and to provide a more humanistic atmosphere in the school environment. The self-paced method used learning activity packages stated with behavioural objectives as a means of allowing for individual differences among students. This method was to allow students to work at their own pace while still providing them with a structured curriculum and goals that were easily identifiable and readily available. The students wrote the tests for each unit of work in the package as they completed the work. A specified level of performance on these tests had to be achieved before the student was allowed to proceed to the next package. If they failed to reach the desired performance level they had to do additional work on the topic and then rewrite the unit test.

The use of learning activity packages allowed students to freely transfer between classes and in most courses to pursue topics that were of interest to them. Within any one class there may be students working on several different topics within that subject. Students could transfer between

classes because the use of learning activity packages allowed them to take partially completed packages with them so that they could finish them under the direction of another teacher or if a course had been completed to enter the next course and start from the beginning. Because students worked at their own pace timetable changes for individual students took place throughout the year. If a course was not completed during the year it was continued in the next year until it was finished and then either the next course was begun or a new course was started.

To bring the students close to the staff the students were assigned to teacher advisory groups. These groups consisted of students all in the same grade and they met with their teacher advisor daily for attendance purposes and for a one hour period during each week. The purpose of the teacher advisory period was to provide each student with one person on the staff of the school who would help them with any academic problems they had, to monitor their progress and to aid the student in adjusting to school life.

Reporting of student progress was done by anecdotal reports that were sent out five times a year. Each teacher wrote a report for each of the students in their classes. Student progress was based on satisfactory completion of the learning activity packages. No letter grades were given. The rate of progress of completing the learning activity packages was reported along with comments about students'

attitude, behaviour and the progress of the student in relation to their ability.

It was a goal of the school to provide students with opportunities for decision-making so that they would develop into responsible members of society. As a means of providing students with decision-making opportunities, students assigned themselves into courses during an arena scheduling. Students chose the courses they would take from the courses they were required to enroll in and those that they elected to take. They could choose among the teachers that offered a particular course. Each class was limited by the space available in the classroom and by the student load that a teacher could reasonably manage. This procedure applied to students in Grades nine to twelve but not to Grade eight students who were assigned to classes by computer. This system of arena scheduling was dropped in favour of computer assignment of all students to courses. The computerized procedure was introduced for all students in 1977, the year after this study, and has been used since then.

It was after three years of operation that major changes began to take place. The English and Social Studies departments stopped using the learning activity packages during the year of this study. They instituted a teacher-paced group approach to teaching. The same method was used in this study as a control. The result of this change was that students could not freely transfer from one class to another in either

of these subject areas. This meant that the freedom to move between other subject areas in the school was greatly restricted. This was seen as a major change in the structure of the school and certainly the teaching method. It was at this point of time that the present study was initiated as a menas of gathering data on the effectiveness of the experimental teaching method so that a more data based decision could be made with regards to which teaching method to use.

2.4 General Questions

The effectiveness of the self-paced method could be investigated by considering dependent variables other than those mentioned in Chapter One. There were other forces at work that were having a greater effect on the decision-making process. These included the anxiety produced by students not completing courses, the general conservatism that pervades education, the anxiety that teachers felt in their new roles and the increased workload that teachers had with this new teaching method. These problems were more administrative than educational.

Perceived Anxiety

The anxiety caused by students not completing their course work within the school year was felt by the students, their parents, the teachers and administration of the school. The effect of this was to cause a chain reaction with regard.

to the anxiety one group felt being passed along to the next. The hierarchy was such that parents and students interacted, passed their concerns on to teachers and administrators, and teachers passed their concerns on to administrators. The solution to the problem of students not completing their course was to have the learning activity package, self-paced system replaced for all English and Social Studies classes as a first step. As a result the flexibility of the timetable was greatly reduced. Students could no longer transfer freely from one class to another, so for all practical purposes it mattered little if the rest of the subject areas were prepared to allow students to work at their own rate because if they finished early there was no other class to transfer into. Completion of the work presented more of an administrative problem than an educational one. What do we do with students who fail to complete the work assigned in a course within the prescribed time? The self-paced method presented us with the problem and with a solution. The solution was to continue the work the following year. But this solution was rejected. It should be noted that students may not be any more successful at completing the work under the conventional teaching method, but their lack of completion goes unnoticed because the students receive a lower grade. With the self-paced method any discrepancy in completion means the course is incomplete, not a lower grade.

Conservatism

The general conservatism of education and of educators was another contributing factor in the decision to abandon the self-paced teaching method. Teachers and administrators, in the school, got "cold feet" when problems started to arise. Instead of looking for ways to solve them, they went back to the "tried and true" method that they had used previously. Teachers and administrators brought to the self-paced method the same attitudes and expectations they had previously held with the more conventional teaching methods. The literature indicates that there is a much greater variation in student learning rates than we might have expected. We should therefore expect that if the learning activity packages were written at a difficulty level appropriate to the average student there would be some students who would not complete the work within the time provided. But, when this occurred it was not dealt with in an effective way. The self-paced method was abandoned in favour of the more conventional teacher-directed method.

Changing roles

The self-paced teaching method changed the roles of teachers substantially. They now had to become curriculum developers and innovators as well as curriculum implementers. Their role with regards to the use of curriculum materials

changed from being a director to being a facilitator. Once they "lost" their position at the front of the room many became insecure. They became anxious about whether the students would "find the answer" within the LAP's. They felt much more secure in their position as a teacher in the more conventional method that put them at the front of the room directing the "learning", instead of having each student as his own learning director. The student had considerable assistance in this role both from the classroom teacher and his teacher advisor. One problem that arose from the self-paced method was that teachers often had to answer the same question or solve the same problem many times. This became very bothersome for most teachers. But, which is of more value, an answer at the time the student raises the question or an answer to a question the student does not have yet?

Teachers' roles also changed when they became an advisor to a group of students. Every teacher and administrator was involved in this process. Some teachers felt very insecure when they had to deal with students on a personal level. They had nothing to say to them! Instead of trying to overcome their initial uneasiness they shrank away from this role and soon began agitating to do away with the teacher advisory period. It has since been reduced to meeting once very other week and now in many cases is used as a study period instead of an advisory period.

Teacher workload

Teacher workload was expanded with the use of the self-paced teaching method. Aside from their teaching load they were expected to be curriculum designers and innovators at the same time. In a review of curriculum and instruction, Fullan and Pomfret (1977) cite a study done by House in which he clearly put the case that teachers find themselves in when new programs are introduced. Hosue stated that "the costs to teachers include the amount of energy, time, difficulty, and trauma involved in learning new skills" and that, by and large, teachers are expected to bear these costs "at their own expense." This clearly indicates the situation that existed at Frank Hurt at the time of this study. It was after the third year of operation of the school, the years previous to this study, that several members of staff left the school. These people had all been involved in the development of the experimental teaching method within the school. It can be conjectured that the tremendous workload that they had for three years was a key factor in their decision to leave.

Although the factors mentioned above are important when considering the overall effectiveness of a teaching method, this study was limited to the effects that the self-paced method had on student outcomes. This was done in order to keep the study to a manageable size.

CHAPTER 3

METHOD OF STUDY

3.0 Introduction

A 2 x 2 x 2 (treatment-by-gender-by-teacher) non-equivalent control group design (Campbell and Stanley, 1963, pp. 47-50) was used to test the hypotheses of no differences between the means of self-paced and teacher-paced classes, means of boys and girls, and the interaction effects produced by these two factors on each of the dependent variables considered. In what follows, the components of this design, including description of the subjects, teaching methods, instruments, design of the study, data preparation, and analyses are described.

3.1 Subjects

3.1.1 Description of the Subjects

The subjects in this study were Grade eight students enrolled in Science Eight at Frank Hurt Secondary, in District #36, Surrey. Since students had no previous experience with the experimental teaching method used in this study, it was felt that there would be no confounding effect due to previous exposure. This school provided a natural setting for this experiment because the learning activity package method of teaching had been used in the school for two years prior to

this study and was in the process of being phased out. The school as a whole was returning to more conventional methods of teaching.

Frank Hurt Secondary enrolls students in five grades, from the eighth to twelfth grade. At the time of this study there were approximately 650 students enrolled. The school is located on 77th Avenue in the Newton area of Surrey. This area was classified, in the accreditation report, as being a greater educational needs area, following the guidelines put forth by the British Columbia Teacher's Federation. The students in this school come from middle class or lower middle class families.

3.1.2 Selection of the Subjects

Students

Four classes of Science Eight, taught by two science teachers during the first trimester of the school year, took part in this study. These classes were selected because they were taught by teachers who had previous experience within this school using the learning activity packages. The treatments were randomly assigned to the classes so that each teacher had an experimental and control group.

The students were assigned to classes by a computer program which was initially considered to be equivalent to random selection, thereby providing no bias, for the purpose of this study. On more careful examination it was discovered that a small class of 13 Band students and a stratification of

Mathematics programming based on previous success in mathematics made this randomization assumption suspect.

It was not thought that the assignment of the Band students would be a serious problem in forming equivalent groups as they would have been in one of the remaining five classes of Science Eight, three of which were included in this study. Also, they were only 13 of the 148 students that were enrolled in Science Eight during that year.

The mathematics classes were stratified into three levels: one class was for the most successful students, three classes for average students, and two classes for the lower ability students. The class for the most capable mathematics students did not conflict with any of the science classes. One of each of the classes for average and lower ability mathematics students occurred during the time that a science class that was included in this study took place, however these two mathematics classes did not occur in the same block. The chance of students in these two mathematics classes being included in this study was reduced because there were only three of the five classes of science that they could be assigned to that were selected for this study. It was not thought that the formation of mathematics classes on the basis of ability grouping introduced very much bias to the formation of science classes because of the small overlap of mathematics and science classes in the timetable.

Campbell and Stanley (1963) point out that the use of naturally formed classes in experiments is an acceptable procedure in the social sciences when random assignment of subjects to treatment is not possible. However, as described later, a preliminary analysis was performed to test the initial comparability of the "experimental" groups.

Table 1

Characteristics of the Four Classes

	Class	Size	Male	Female
Teacher 2	1*	19	11	8
	2**	23	6	17
Teacher 1	3*	17	10	7
	4**	15	8	7

* experimental treatment
** control treatment

Teachers

The two teachers who took part in this study were both male and were experienced science teachers. One teacher had taught for two years in Africa before joining the staff of Frank Hurt. He had taught two years at Frank Hurt before this study was initiated. The author, who was the second teacher, had taught science in a junior high school in Surrey for five years prior to joining the staff at Frank Hurt. He also had

taught at Frank Hurt for two years prior to the initiation of this study. Both teachers were between 30 and 35 years of age. A third teacher available for inclusion in the study was ruled out because she was a beginning teacher in her first year of teaching.

3.2 Teaching Methods

3.2.1 Self-Paced

Saliant features of the experimental teaching method are its stress on student self-pacing and the use of learning activity packages (LAP's) with stated behavioural objectives. The LAP used in this study consisted of a sequential outline of activities for studying optics, the objectives for each unit, and the specific objectives for each sub-unit. Once the students had been shown how to use the package and where they would find the materials they needed, they were allowed to proceed at their own pace. The students worked either alone or in small groups. Students wrote the course exams set by the teachers when they finished each sub-unit of work.

3.2.2 Teacher-Paced

The conventional teaching method used here as a control against which the experimental method could be compared was teacher directed, teacher-paced. Behavioural objectives were not provided to the students; instead the work for each day was presented by the teacher to the whole class of students.

The exams, the same ones the self-paced students wrote, were set by the teacher after each sub-unit of work and were written by the whole class. A copy of an example lesson of each program and a unit test is provided in Appendix A.

3.3 Design of the Study

A 2 x 2 x 2 (method-by-teacher-by-gender) non-equivalent groups fixed effects factorial design was used in the present study. Factor 1, method, was subdivided into experimental and control. Factor 2, teacher, was subdivided into teacher 1 and teacher 2. This factor was included as part of the design in order to control for any differences between teachers. Factor 3, gender, was subdivided into male and female.

3.4 Instruments

3.4.1 Achievement Test

The test used to measure achievement and retention of knowledge, developed by the investigator, consisted of 59 multiple-choice items referenced to behavioural objectives of the optics learning activity package. Content validity was established by having the second teacher compare the items on the test with the objectives in the package. All items on the test were retained. A copy of this test is in Appendix B.

3.4.2 Test of Science Processes

A modified version (Mott, 1974) of Tannenbaum's Test of Science Processes (1971) was used to provide a measure of

knowledge of science processes. It is a 50 item multiple-choice test. Mott prepared his modification by taking the 50 items which yield the highest KR-20 estimate of internal consistency, using the responses of students in Grade eight collected by Sieben (1971). The number of items for each type of process evaluated is shown in Table 2.

Tannenbaum (1971), using KR-20, reported a reliability of the original 96 item test to be .91; Sieben (1971) reported a reliability of this same test to be .89. A calculation using the Spearman-Brown formula (Cronbach, 1949), yielded a reliability for the shortened test of .84. A mean of 33.032 and standard deviation of 7.387 were reported by Mott (1974) for the modified version of the Test of Science Processes.

Table 2

Number of Items for Each Type of Process

Type of Process	Number of Items of Modified Test
Observing	6
Comparing	2
Classifying	2
Quantifying	8
Measuring	12
Experimenting	6
Inferring	8
Predicting	6
Total Number of Items	50

3.4.3 Attitude Scales

The two attitude scales used were Form X and Form Z developed by Sieben (1971). Form X, called here the attitude to experimenting, is an attitude scale developed to measure whether or not experimenting in science leads students to pursue phenomena that they notice. The second attitude scale, Form Z, called here the attitude to independent investigation, is an attitude scale developed to measure whether or not experimenting leads students to investigate independently. These two tests were chosen because the two variables they measured were thought to be important in determining success in science as taught by the learning activities package method.

Sieben (1971) reported the reliability to be .82 for each attitude scale as calculated by Cronbach's alpha. Sieben (1971) reported the mean of Form X to be 50.22 and the standard deviation to be 13.35 and the mean of Form Z to be 45.12 and the standard deviation to be 13.54.

3.4.4 Hidden Figures Test

As discussed below, an analysis of covariance was used to analyze the achievement scores. The covariate used was an adaptation of the Hidden Figures Test (Witkin, 1972) which provided a measure of cognitive style. It has been found that there is a relationship between cognitive style and achievement in science. Witkin, et al. (1977) reviewed

studies that investigated the relationship between cognitive style and achievement in science. They came to these conclusions:

> "In a good majority of the large number of studies with college populations, relatively field-independent students were found to perform significantly better in mathematics, sciences, engineering, and architecture domains than field-dependent students..." (p. 45)

> "It is noteworthy that relationships between cognitive style and achievement appear despite the restricted range in cognitive style scores likely to occur in groups filtering into these domains." (p. 46)

> "Studies of the relation between cognitive style and performance have been less frequent with high school students than with college students, and their results not as clear. In only about half of the studies with high school students now on record was the relation between mathematics-science achievement and measure of field-dependence-independence significant, although in every study, the difference in performance as a function of cognitive style was in the expected direction." (p. 46)

The Hidden Figures Test used in the present study was an adaptation used earlier by Grimes (1973) and Mott (1974). It is a group administered test consisting of 32 items. Each item requires the subject to identify a simple shape within a complex field. The test is divided into two 16 item subtests. Grimes (1973) reported that the internal consistency, computed using KR-20, was 0.92. Mott (1974) reported the mean for this test to be 22.860 and the standard deviation to be 7.705. A copy of this test is provided in Appendix B.

3.5 Administration of Instruments

The achievement test was administered at the end of the three month teaching phase. It was administered by the class teacher during the regular 60 minute class period and all classes were tested on the same day. This was done to minimize any discussion of the test between students who had written the test and those who had not yet written the test. Students were asked not to discuss the test with others. The retention test was given 90 days after the post achievement test and all classes were given the test by the author during their 60 minute science period. The whole class was tested at the same time and subjects remained in their original classes.

The Hidden Figures test was administered to the students during the first two weeks of school. The test was administered to all classes during their regular science period. The directions on the front of the test, a copy of which appears in Appendix B, were followed. Ten minutes was allowed for each part of the test and students were not allowed to proceed if finished Part 1 early or to return to Part 1 once Part 2 of the exam was started.

The Test of Science Processes, modified version, was given to the students within the week following administration of the achievement test. This test was administered to all subjects by the author. The directions at the beginning of the exam (see Appendix B) were read to the students and the

students followed on their copy of the test. A one hour time period was given to complete the test. There were some problems in distinguishing the pictures presented in some questions. The students were informed of these at the beginning of the test period and drawings similar to the pictures were put on the board at the front of the room so that all students could see them.

The attitude scales test was given twice to each student: once within the first week of school and again at the end of the teaching unit, following the achievement test and the Test of Science Processes. The author administered the test to all classes on both occasions. The directions were read out to the class and questions were then answered. The students were given time to do the practise questions. The test was then read out to the students, question by question, and the students were given time to respond after each question. This was done for two reasons.

1. So that students would think about each question before answering it.
2. To ensure they understood each question's meaning.

3.6 Data Preparation and Analysis

3.6.1 Data Preparation

The data collected were coded by the author and verified by randomly selecting the data for ten subjects and recoding this data. Results of this verifying procedure showed no

errors. The data were keypunched with 100% verification by the University of British Columbia computing center staff.

3.6.2 Test Analysis

An item analysis of the post-test and retention test data was performed and an estimate of internal consistency (Hoyt, 1941) was computed using the LERTAP (Laboratory of Educational Research Test Analysis Package), Nelson (1974), computer program maintained by the Educational Research Service Centre. The Hoyt estimate of internal consistency of the post-test is .82 and .76 for the retention test. The post-test has a mean of 31.74 and a standard deviation of 7.98. The mean for the retention test is 30.16 and the standard deviation is 6.74.

An item analysis of the two attitude scales data was performed and an estimate of internal consistency (Hoyt, 1941) was computed using the LERTAP computer program. The Hoyt estimates of reliability were .67 and .73 for the pre- and post-test scales that measure the attitude to experimenting. The mean and standard deviation were 47.38 and 10.11 respectively, for the pre-test and 46.35 and 12.87 respectively, for the post-test. The Hoyt estimates of reliability were .85 and .85 for the pre- and post-test scales that measure the attitude to independent investigation. The mean and standard deviation were 46.35 and 12.87 respectively, for the pre-test and 55.30 and 13.52 respectively, for the post-test.

3.6.3 Preliminary Analysis

A preliminary analysis of the pre-test data was performed to examine more closely the equivalence of the groups formed. A 2 x 2 x 2 (method-by-teacher-by-gender) fixed effects analysis of variance (Winer, 1971) was used to separately analyze the scores obtained on the Hidden Figures Test and each of the two attitude scales. The results of these analyses are summarized in Appendix C. As shown in Tables 3, 4 and 5 there was a significant interaction effect between sex and teacher. Thus, to eliminate this source of bias and to realize a possible increase in power due to the use of a covariate, the Hidden Figures Test was retained and analyses of covariance employed to analyze all the data.

Table 3

Summary of Analysis of Variance of Hidden Figures Test Scores

Source of Variance	Degrees of Freedom	Mean Square	F	Probability
Sex (S)	1	162.701	2.06	0.156
Teacher (T)	1	21.895	0.28	0.601
Treatment (Tr)	1	87.791	1.11	0.296
S x T	1	3.405	0.04	0.836
S x Tr	1	317.790	4.02	0.049
T x Tr	1	0.956	0.01	0.913
S x T x Tr	1	73.680	0.93	0.338
Residual	65	79.076		

Table 4

Summary of the Analysis of Variance of the Attitude to Experiment Scores

Source of Variance	Degrees of Freedom	Mean Square	F	Probability
Sex (S)	1	36.987	0.37	0.544
Teacher (T)	1	183.589	1.84	0.179
Treatment (Tr)	1	57.558	0.58	0.450
S x T	1	0.324	0.00	0.955
S x Tr	1	23.062	0.23	0.632
T x Tr	1	414.336	4.16	0.045
S x T x Tr	1	2.401	0.02	0.877
Residual	66	99.593		

Table 5

Summary of the Analysis of Variance of the Attitude to Independent Investigation Scores

Source of Variance	Degrees of Freedom	Mean Square	F	Probability
Sex (S)	1	7.405	0.07	0.797
Teacher (T)	1	7.026	0.06	0.803
Treatment (Tr)	1	56.652	0.51	0.478
S x T	1	155.582	1.40	0.242
S x Tr	1	168.091	1.51	0.224
T x Tr	1	1388.437	12.46	0.001
S x T x Tr	1	2.647	0.02	0.878
Residual	66	111.403		

3.6.4 Final Analysis

The use of Design 10 and the preliminary results led to the decision to use a 2 x 2 x 2 (method-by-teacher-by-gender)

fixed effects analysis of covariance to separately analyse achievement, retention, and science processes scores using Hidden Figures scores as the covariate. The analysis of the attitude scales was a 2 x 2 x 2 (method-by-teacher-by-gender) fixed effects analysis of covariance that separately analysed the attitudes to experimenting and independent investigation using the pre-test scores respectively as covariates. The level of significance used for all analysis was the .05 level.

All analyses were completed on an AMDAHL 470 Model V/6 Mark 2 using the program ANOVAR, Statistical Package for Social Sciences (Nie, N.H., et al., 1975).

CHAPTER 4

ANALYSIS OF DATA

4.0 Introduction

The results of the analyses described in Chapter Three are presented in this chapter. In what follows, the results of those analyses, the final sample sizes realized are presented, followed by a discussion of the psychometric characteristics of each of the measures used. The chapter concludes with a presentation of the analyses of covariance performed on each of the dependent variables considered.

4.1 The Final Sample

The final sample, consisting of 74 subjects distributed in four classes as shown in Table 6, was derived from the initial sample of 104 subjects. Attrition, due to missing data or leaving the class, accounted for the difference between the number of subjects in the initial and final samples.

Table 6

Summary of Initial and Final Cell Sample Size

		Teacher 1		Teacher 2	
		Teacher-Paced	Self-Paced	Teacher-Paced	Self-Paced
Initial Sample	n =	23	28	24	29
	male =	14	18	13	9
	female =	9	10	11	20
Final Sample	n =	17	15	19	23
	male =	10	8	11	6
	female =	7	7	8	17

4.2 Summary of Analysis of Instruments

Science achievement and retention

The results for the achievement test are given in Table 7. The item difficulty and item test correlation discrimination index (point-biserial correlation coefficients) for both tests are given in Appendix B. The difficulty indices vary from .095 to .946 on the post-test and from .081 to .973 on the retention test. The discrimination indices vary from -0.10 to 0.59 on the post-test and from -0.20 to 0.58 on the retention test. All 59 items, on both tests, were retained for subsequent analysis.

Table 7

Summary of Achievement Test

	Post	Retention
Mean	31.74	30.16
Standard Deviation	7.98	6.74
Range	15.00 - 50.00	16.00 - 48.00
Hoyt estimate of internal consistency	0.82	0.76
Standard error of measurement	3.33	3.29

Attitude Scales

The results for the attitude scales, administered as pre- and post-tests, are given in Table 8. Item-test correlations are given in Appendix B for both attitude scales, and both occasions. The item-test correlations for the experimenting

Table 8

Summary of Pre- and Post-Attitude Scales

	Pre		Post	
	Experimenting	Independent Investigation	Experimenting	Independent Investigation
Mean	47.38	54.27	46.35	55.30
Standard deviation	10.11	11.09	12.87	13.52
Range	20.00 - 68.00	32.00 - 82.00	22.00 - 80.00	23.00 - 86.00
Possible Range	20.00 - 100.00	20.00 - 100.00	20.00 - 100.00	20.00 - 100.00
Hoyt estimate of internal consistency	0.67	0.73	0.85	0.85
Standard error of measurement	5.64	5.65	4.83	5.11

attitude scale vary from -0.045 to 0.471 on the pre-test and from -0.036 to 0.658 on the post-test. The item-test correlation for the attitude scale called independent investigation vary from 0.080 to 0.581 on the pre-test and from 0.083 to 0.654 on the post-test. All 20 items were retained for both attitude scales.

Item means and standard deviations for the two attitude scales that comprise the two administrations of the tests are given in Appendix B.

4.3 Summary of Analysis of Covariance

Achievement Post-Test Scores

In order to determine whether the differences in the mean scores on the achievement post-test are due to methods of instruction, the teacher, or the sex of the student, a 2 x 2 x 2 fixed effects analysis of covariance was done using the Hidden Figures scores as the covariate. The results of this analysis are given in Table 9. As shown in Table 10, the results show the teacher effect to be the only significant effect. The means for these two groups are given in Table 10. An examination of these means shows that the achievement post-test mean is the greatest for Teacher 2.

Retention Test Scores

The results of the analysis of covariance performed for the retention test scores are presented in Table 11. There are no

Table 9

Summary of Analysis of Covariance of Achievement Post-Test Scores

Source of Variance	D.F.	Mean Squares	F	Probability
Covariate				
Hidden Figures	1	272.134	4.964	0.029
Main Effects				
Sex (S)	1	67.189	1.226	0.272
Teacher (T)	1	264.192	4.819	0.032
Treatment (Tr)	1	174.069	3.175	0.079
2-Way Interactions				
S x T	1	23.300	0.425	0.517
S x Tr	1	142.204	2.594	0.112
T x Tr	1	39.170	0.715	0.401
3-Way Interactions				
S x T x Tr	1	142.805	2.605	0.111
Residual	64	54.818		
Total	72			

Table 10

Cell Sample Size and Adjusted Means Achievement Post-Test

		Gender	
Treatment	Teacher	Male	Female
Self-Paced	1	n = 8	n = 6
		$\bar{x}$ = 32.50	$\bar{x}$ = 33.33
	2	n = 6	n = 17
		$\bar{x}$ = 40.17	$\bar{x}$ = 31.59
Teacher-Paced	1	n = 10	n = 7
		$\bar{x}$ = 28.20	$\bar{x}$ = 25.43
	2	n = 11	n = 8
		$\bar{x}$ = 32.00	$\bar{x}$ = 33.63

Table 11

Summary of Analysis of Covariance of Retention Test Scores

Sources of Variance	D.F.	Mean Squares	F	Probability
Covariate				
Hidden Figures	1	471.474	12.519	0.001
Main Effects				
Sex (S)	1	14.202	0.377	0.541
Teacher (T)	1	145.024	3.851	0.054
Treatment (Tr)	1	76.117	2.021	0.160
2-Way Interactions				
S x T	1	75.413	2.002	0.162
S x Tr	1	64.267	1.706	0.196
T x Tr	1	0.263	0.007	0.934
3-Way Interaction				
S x T x Tr	1	48.780	1.295	0.259
Residual	64	37.661		
Total	72			

significant main or interaction effects for the retention test scores. Both treatments were as effective for both sexes of subjects as taught by either teacher.

Science Processes Test Scores

An analysis of covariance was done using Hidden Figures scores as the covariate. The results of this analysis are shown in Table 12. Significant differences were obtained for treatment and for the sex by treatment interaction. The means corresponding to these factors are given in Table 13.

The means for the treatment effect show that the self-paced group scored higher on the Science Processes Test than did the teacher-paced group. However, the sex by treatment interaction mitigates against a simple interpretation of the main treatment effect.

Table 12

Summary of Analysis of Covariance of Science Processes Test Scores

Source of Variance	D.F.	Mean Squares	F	Probability
Covariate				
Hidden Figures	1	492.189	13.117	0.001
Main Effects				
Sex (S)	1	66.399	1.770	0.188
Teacher (T)	1	12.306	0.328	0.569
Treatment (Tr)	1	273.971	7.302	0.009
2-Way Interactions				
S x T	1	3.743	0.100	0.753
S x Tr	1	358.970	9.567	0.003
T x Tr	1	12.031	0.321	0.573
3-Way Interaction				
S x T x Tr	1	20.114	0.536	0.467
Residual	64	37.522		
Total	72			

Table 13

Cell Sample Size and Adjusted Means Science Processes Test

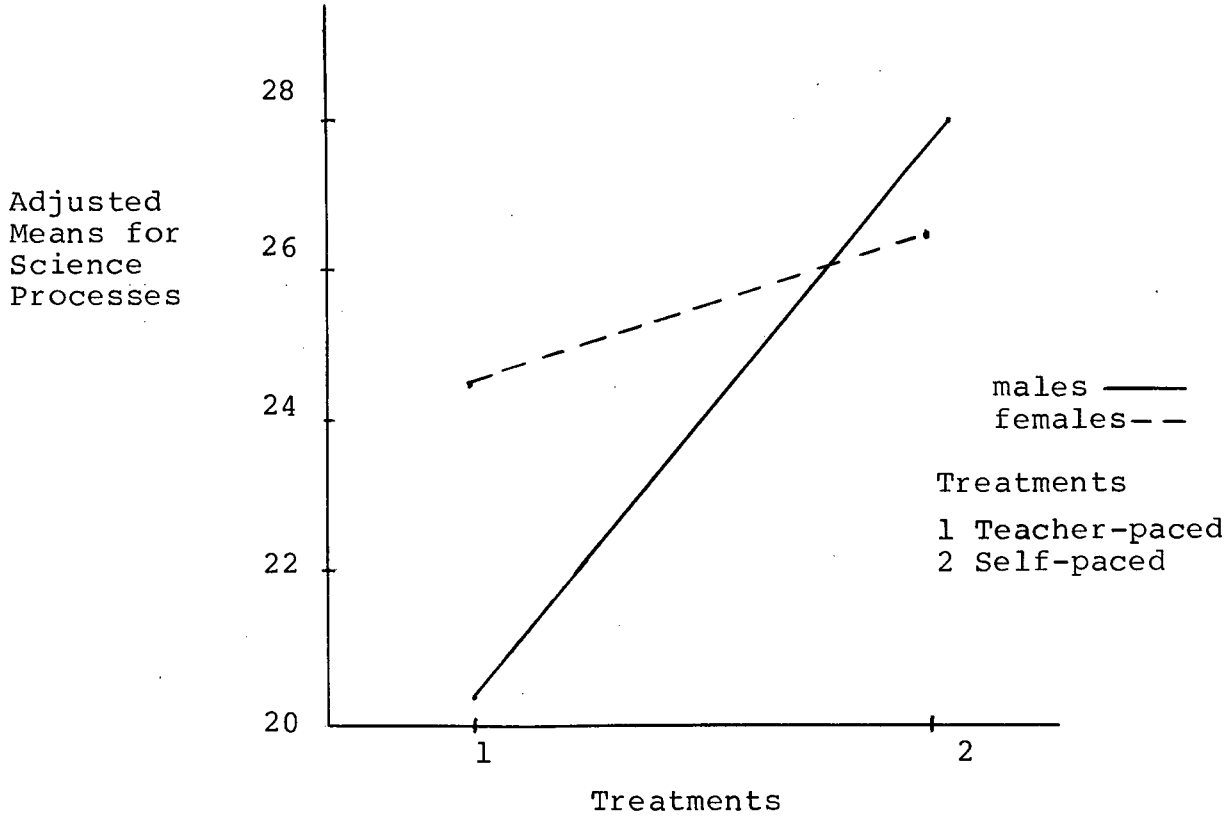
		Gender	
Treatment		Male	Female
Self-Paced	n = 37	n = 14	n = 23
	$\bar{x}$ = 26.81	$\bar{x}$ = 27.93	$\bar{x}$ = 26.13
Teacher-Paced	n = 36	n = 21	n = 15
	$\bar{x}$ = 21.89	$\bar{x}$ = 20.19	$\bar{x}$ = 24.27

A graphical analysis was done for the interaction in order to better interpret the interaction. Figure 1 shows the mean Science Processes scores plotted against treatment for both

sexes. Means of Science Processes for these groups are from Table 13.

Figure 1

Science Processes Means vs. Treatments



The graphical analysis shows that the interaction between treatment and sex is of a disordinate nature (Glass & Stanley, 1971, p 410-411). Males in the self-paced group appeared to have scored significantly better than males in the teacher-paced group. In contrast female students in both groups were more comparable although they scored higher in the self-paced

group than in the teacher-paced group. However, the difference does not appear to be significant.

Attitude Scale

An analysis of covariance was done separately for each of the attitude scales using the corresponding pre-test scores as the covariate. Table 14 shows the summary of the analysis of covariance of the attitude to experiment test scores. There are two significant interactions; sex by teacher and treatment by teacher. For each of these interactions a graphical analysis was done. Table 15 contains the means for these effects.

Figure 2 shows the graphical analysis for the sex by teacher interaction. Means were taken from Table 15.

The graphical analysis indicates that Teacher 1 had a more positive effect on the attitude to experimenting of males than of females. It further indicates that Teacher 1 had a more positive effect on the attitude to experimenting of males than had Teacher 2 and that Teacher 2 had a more positive effect on the attitudes of females to experimenting than Teacher 1. There was no significant difference between males and females in their attitude to experimenting when taught by Teacher 2.

Table 14

Summary of Analysis of Covariance of the Experiment Attitude Scale

Source of Variance	D.F.	Mean Squares	F	Probability
Covariate				
Pre-test	1	2971.201	27.957	0.000
Main Effects				
Sex (S)	1	370.126	3.483	0.067
Teacher (T)	1	24.268	0.228	0.634
Treatment (Tr)	1	145.081	1.365	0.247
2-Way Interactions				
S x T	1	1352.076	12.722	0.001
S x Tr	1	80.128	0.754	0.388
T x Tr	1	552.993	5.203	0.026
3-Way Interaction				
S x T x Tr	1	9.100	0.086	0.771
Residual	65	106.276		
Total	73			

Table 15

Cell Sample Size and Adjusted Means Experiment Attitude Scale

		Teacher 1	Teacher 2
Gender	Male	n = 19	n = 17
		$\bar{x}$ = 53.37	$\bar{x}$ = 45.00
	Female	n = 13	n = 25
		$\bar{x}$ = 38.46	$\bar{x}$ = 46.04
Treatment	Self-paced	n = 15	n = 23
		$\bar{x}$ = 52.20	$\bar{x}$ = 42.74
	Teacher-paced	n = 17	n = 19
		$\bar{x}$ = 43.00	$\bar{x}$ = 49.11

Figure 2

Attitude to Experimenting Scores vs. Teacher

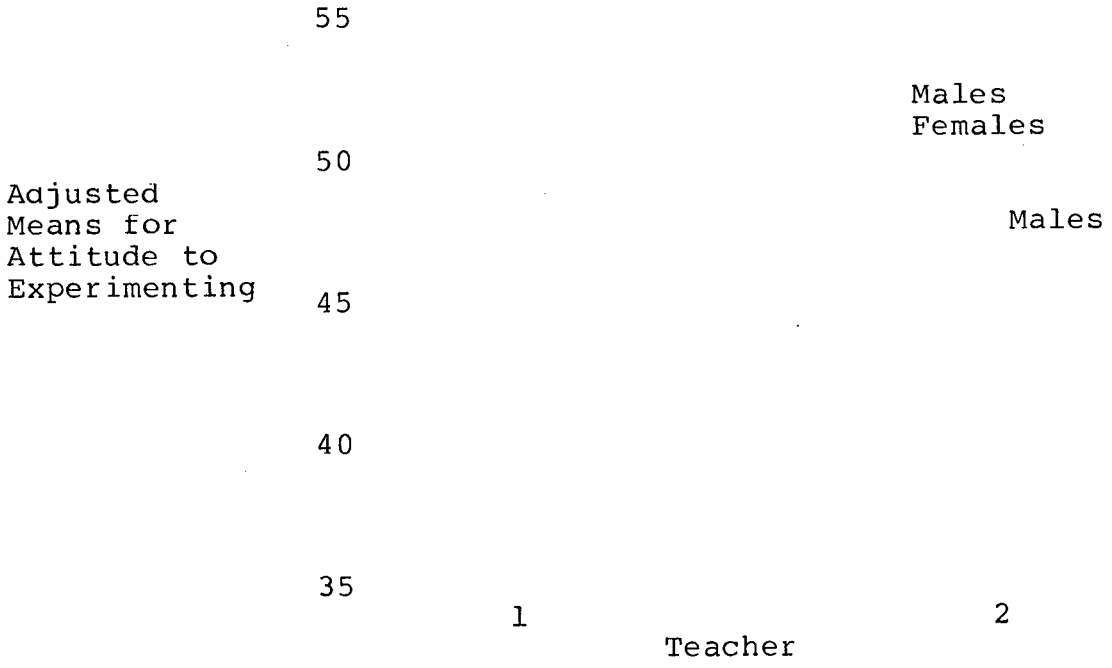
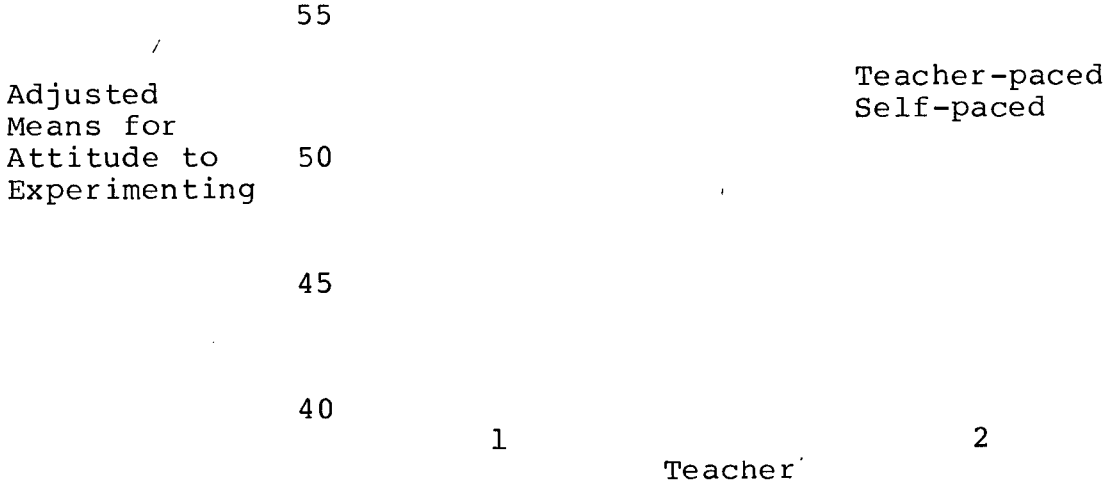


Figure 3 shows the graphical analysis for the teacher by treatment interaction.

The graphical analysis indicates that the self-paced method had a greater effect on the attitude to experimenting when taught by Teacher 1 and conversely the teacher-paced method had a greater effect when taught by Teacher 2. Further it indicates Teacher 1 had a greater effect on attitude to experimenting when using the self-paced method than when using the teacher-paced method. In contrast, Teacher 2

Figure 3

Attitude to Experimenting Mean Scores vs. Teacher



had a greater effect on the attitude to experimenting when using the teacher-paced method than when using the self-paced method.

Table 16 shows the summary of the analysis of covariance of the attitude scale for independent investigation. There is one significant interaction effect between teacher and treatment. Table 17 shows the means for this interaction effect.

A graphical analysis was done to determine the nature of the teacher by treatment interaction. Figure 4 shows the results of this analysis. Means for these groups are from Table 17.

Table 16

Analysis of Covariance of the Independent Investigation Attitude Scale

Source of Variance	D.F.	Mean Squares	F	Probability
Covariate				
Pre-test	1	6373.473	70.785	0.000
Main Effects				
Sex (S)	1	213.236	2.368	0.129
Teacher (T)	1	160.373	1.781	0.187
Treatment (Tr)	1	76.178	0.846	0.361
2-Way Interactions				
S x T	1	126.870	1.409	0.240
S x Tr	1	59.130	0.657	0.421
T x Tr	1	679.212	7.543	0.008
3-Way Interaction				
S x T x Tr	1	11.230	0.125	0.725
Residual	65	90.040		
Total	73			

Table 17

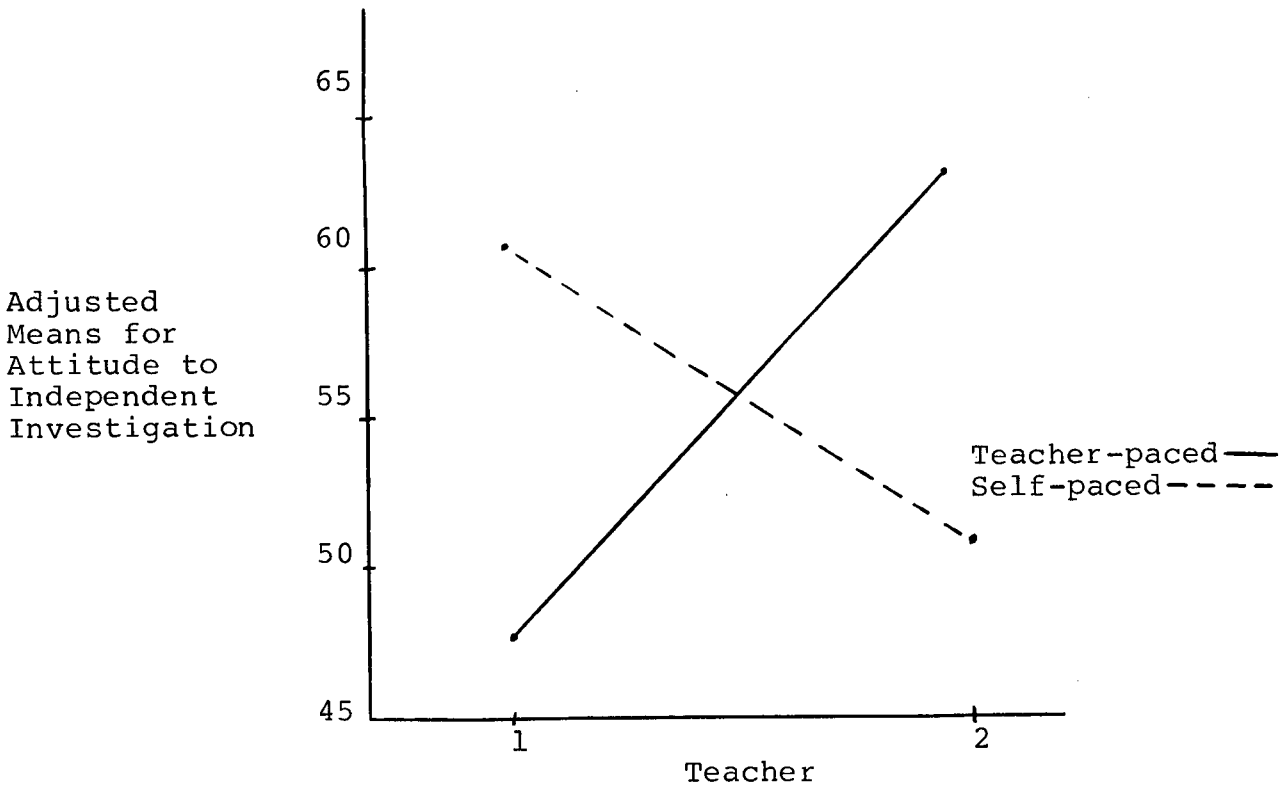
Cell Sample Size and Adjusted Means
Independent Investigation Attitude Scale

		Self-paced	Teacher-paced
Teacher	1	$n = 15$	$n = 17$
		$\bar{x} = 60.53$	$\bar{x} = 47.00$
	2	$n = 23$	$n = 19$
		$\bar{x} = 51.74$	$\bar{x} = 62.89$

The graphical analysis indicates the same interactions as for the teacher by treatment interaction with the attitude

Figure 4

Attitude to Independent Investigation vs. Teacher



to experimenting. Teacher 1 had a greater effect on the attitude to independent investigation when using the self-paced method than when using the teacher-paced method. In contrast Teacher 2 had a greater effect when using the teacher-paced method. Again, the self-paced method was more effective when taught by Teacher 1 and the teacher-paced method was most effective when taught by Teacher 2.

The results of the analyses have been presented in this chapter. The implications of the results of the analyses will be discussed in the following chapter.

CHAPTER 5

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

5.0 Introduction

This investigation grew out of a perceived need, by the author, to determine the relative effectiveness of two teaching methods, the self-paced and teacher-paced methods. The school in which this study took place had been using a self-paced method and was in the process of changing to a teacher-paced method. In what follows, the differential effectiveness of these two methods will be discussed and recommendations for further research will be made.

5.1 Conclusions

The analyses, as reported in chapter four, have provided evidence to answer the question represented by the null hypotheses that were stated in chapter one and to thereby determine the relative effectiveness of the two teaching methods.

The relative effectiveness of the two teaching methods has been determined. The null hypothesis regarding the effect of teaching method on the dependent variable, understanding of science processes, was rejected. However there

was a significant interaction effect between the sex of the student and the teaching method. The self-paced method of teaching was found to be significantly better than the teacher-directed method, for teaching an understanding of science processes. The interaction between the sex of the student and teaching method demonstrated that males scored much higher on the Test of Science Processes when taught with the self-paced method and that females also scored much higher on the Test of Science Processes with the self-paced method but the difference, between the scores, attributable to the teaching method was not as great as it was for males.

The null hypothesis regarding the effects of teaching method on the dependent variables: achievement in science, retention of science knowledge, students' attitudes to experimenting, and independent investigations were not rejected. No significant difference between the teaching methods was found for these variables. It should be noted however, that there are significant interactions involving teaching method for the dependent variables, students' attitude to experimenting and independent investigations.

The significant interactions involving teaching method include teacher as the other factor. These interactions were found to be significant for both of the attitude scales. A clear preference for a particular teaching method was shown by both teachers. Teacher one preferred the self-paced

method and Teacher two preferred the teacher-directed method. As a result the attitudes of students to experimenting and independent investigation varied according to which teaching method was used by their teacher. Students taught by Teacher one using the self-paced method scored higher on both attitude scales than students taught by Teacher one using the teacher-paced method. Conversely, students taught by Teacher two using the teacher-paced method scored higher on the two attitude scales than students taught by Teacher two using the self-paced method.

The null hypotheses regarding sex of the student and the five dependent variables are all accepted. No significant differences were found between the mean scores of males and females on the five dependent variables. Significant interactions involving the sex of the student were found. As mentioned earlier there was a significant interaction between the sex of the student and teaching method on the dependent variable, understanding of science processes. A highly significant interaction was found between the teacher and the sex of the student for the dependent variable, students' attitude to experimenting. Males taught by Teacher one scored higher than females taught by Teacher one. The males taught by Teacher one scored higher than males taught by Teacher two and females taught by Teacher one scored lower than females taught by Teacher two. There were no apparent differences

in the mean scores for the attitude to experimenting between males and females taught by Teacher two.

The factor Teacher, which it became necessary to control for, was found to have a significant effect. The null hypothesis regarding the dependent variable, achievement in science, was rejected on the basis of the analysis of covariance. The analysis shows that students taught by Teacher two scored significantly higher on the achievement in science test than students taught by Teacher one. The Teacher factor was also involved in significant interaction effects. There were significant interaction effects betwen Teacher and Teaching method for the dependent variables, students' attitudes to experimenting and independent investigations, and between the sex of the student and Teacher for the dependent variable students' attitude to experimenting. Both of these interaction effects were discussed earlier.

On the basis of the rejection of the null hypothesis, regarding the understanding of science processes, in favour of the self-paced method and the acceptance of the null hypotheses for the other dependent variables the self-paced method has been found to be as effective as the teacher-directed method. However, the effectiveness of the teaching method appears to depend upon the teacher who is using it insofar as students' attitudes are concerned.

5.2 Limitations

This study was limited to Grade eight students. This was done so that the effects of the teaching method would not be affected by prior experience with the self-paced method. Although this does reduce the chance of prior experience confounding the results of this study it does restrict the generalizability of the study in that the long term effects of using the self-paced method have not been explored. This study was done over a three month period. What effect the self-paced method has on students' attitudes and achievement in science when this method is used over longer time periods or with students of other grades has not been investigated. The results should be used with discretion outside of the Grade eight population that made up this study.

The involvement of the experimenter as one of the teachers in this study introduced a possible error as the results of the analyses demonstrated that the experimenter exhibited a bias towards the self-paced method of teaching.

The five dependent variables used to compare the two teaching methods in this study are only a small selection from a much larger pool of possible variables that might be used to determine the effectiveness of any teaching method. They have been chosen because they were thought to be relevant to the present study but, they do not exhaust the possible choices for the comparison that has been done.

The lack of random assignment of subjects to treatment level limits the internal validity of this study. However, it should be noted that this study still has a legitimate design although of less power than a true experimental design. The design of this study would be classified as an example of design ten of Campbell and Stanley (1963): that is, a non-equivalent control group design.

> "A design in which the control group and the experimental group do not have pre-experimental sampling equivalence. Rather, the groups constitute naturally assembled collectives such as classrooms, as similar as availability permits..."

As such, caution must be used in applying the results of this study to other situations.

5.3 Inferences

The results of this study indicated that statements could be made regarding the relative effects of the two teaching methods that were investigated, the effect that the teacher has on the effectiveness of a particular teaching method, and the interaction effects of sex of the student and teaching method and teacher. These results substantiate the literature on the teaching methods and the interaction effects of teaching method, teacher and sex of the student.

The self-paced has been found to be as effective or more effective than the teacher-directed method for teaching the cognitive aspects of science. The results of the analyses

show that the self-paced method was superior to the teacher-directed method for teaching an understanding of science processes. In the acquisition and retention of science knowledge the self-paced method is as effective as the teacher-paced method. The self-paced group did as well on the achievement and retention tests as did the control group, even though some students in the self-paced group did not complete the physics unit. These results substantiate the results of the studies done by Kline (1971) and Ketchum (1972) who also found no significant difference between these two teaching methods. The difference in mean scores for the understanding of science processes, in favour of the self-paced method, indicates that the self-paced method should be considered as an alternative to the teacher-directed method. The processes and underlying concepts of science may very well be of longer lasting value and meaning than the knowledge of science facts. But, the interaction between the teaching method and the sex of the student tends to confound the effect of the teaching method. Although the self-paced method was shown to be superior to the teacher-directed method for teaching an understanding of science processes, the difference was largely due to the difference the males showed when taught by these two methods. Males taught by the self-paced method scored significantly higher than males taught by the teacher-directed method. This would, by itself, account for the difference between the two teaching methods. It should be noted however, that females also

scored higher on the Test of Science Processes when taught by the self-paced method, although the difference between the mean scores for the two methods was nowhere as large as it was for males. The self-paced method has been shown to be superior to the teacher-directed method for the teaching of science processes, only for boys, and as effective for the acquisition and retention of science knowledge, for both genders, and therefore should be considered as an alternative to the teacher-directed method.

There is an apparent anomaly in the findings of the teaching method by sex interaction effects. No significant difference between mean scores was found on the achievement and retention measures but a significant difference was found on the Test of Science Processes. Anderson (1980) and Glasser (1976) found similar results of no difference in the interaction effects of teaching method and sex of the student for measures of achievement. No studies specifically looked at science processes. The teaching method used does differentially affect students depending on their sex when measured on their understanding of science processes. Males score significantly higher when a self-paced method is used in preference to a teacher-directed method. Females also score higher with the self-paced method over the teacher-directed method however the difference is not as great as it is for males. The results tend to refute the results found by

Campbell (1972) that females do better with learning activity packages than males do.

The results of the analyses show that the interactions between the teacher and the teaching method are most important in determining the attitudes of students. No differences between teachers or teaching methods were found because the teachers had opposite effects on students' attitudes which depended upon the teaching method used. One teacher highly favoured the self-paced method over the teacher-directed method and as a result student attitudes were more positive in the self-paced group than in the teacher-directed group. The opposite effect was found for the other teacher. These results demonstrated that the teacher was very important in determining the effectiveness of the teaching method on student attitudes and that not every teacher will be able to use every teaching method with equal success. There must be some characteristics that teachers have that interact in some way with the teaching method.

The interaction between the sex of the student and the teacher for the dependent variable attitude to experimenting is in all likelihood a result of teacher bias. One teacher apparently favoured the males over the females and as a result the attitude of males to experimenting was more positive than the attitude to experimenting of females. If there is a connection between attitude and achievement, as suggested by Campbell (1972), then such a bias poses a serious problem in

light of the fact that the vast majority of science teachers at the present time are male. The existence of such biases, on the basis of sex, by teachers needs to be recognized and methods for overcoming it need to be instituted.

The self-paced method has been found to be as effective as the teacher-directed method for teaching the cognitive aspects of science. The effectiveness of the teaching method on the affective aspects of science depends upon some as yet unidentified teacher characteristics. The interaction between these characteristics and the teaching method are what determine the effect that the combination of teacher and teaching method have on students' attitudes. The self-paced method, on the basis of the results of this study, should be considered as an alternative to the more conventionally used teacher-directed method, however an effort needs to be made to match the teaching method with the teacher.

5.4 Recommendations

This study has not attempted to look at the long term effects that the use of the self-paced method of teaching will have on student achievement or attitudes. The three months in which the self-paced method was used in this study is a short time in the time that students spend in school. The effect that this method will have on future success is not known and needs to be determined. Whether student achievement and attitudes will diminish, increase or remain at a

constant level over time and continued use of the self-paced method is not known.

Student attitudes to their teacher or to science have not been explored and need to be if the self-paced method is to be widely used.

The effects of using the self-paced method on the teacher have not been investigated. What changes in teacher workload, morale and the effect that these have on teacher survival have not been explored. Teachers will have little time to innovate if all their time, energy and motivation are used up in trying to raise student success to a mastery effect, construct new materials and manage the program when using the self-paced method.

The teacher characteristics that determine a teacher's effectiveness with a particular teaching method need to be determined. Once this is done then an effort to match a teacher with a suitable method or methods can be made.

The effect that the self-paced teaching method has on other topics in science: in the areas of chemistry, biology, and earth science, have not been investigated. Each of these areas of science have associated with them materials and laboratory procedures that are unique to them. There is a need to determine the effectiveness of the self-paced teaching method with these other areas of science.

5.5 Epilogue

It has been three and a half years since the data collection phase of this study was done. In this time Frank Hurt Secondary has completely phased out the experimental teaching method and adopted the more conventional teaching method. In the seven years the school has been in operation a great many changes have taken place. The major changes took place at the time this study was initiated. Although the self-paced method was introduced in its entirety when the school opened, the changes that have come about have done so gradually over a period of several years.

More recent studies by Fullan and Pomfret (1977) have provided new insights into the process of implementation. Within studies such as theirs there are questions raised about the implementation process that might have been more relevant than the questions raised in this study.

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Appendix

Tannenbaum, 1971, Test of Science Processes, page 105.

Witkin, 1972, Hidden Figures Test, page 99.

A P P E N D I X A

SAMPLE LESSONS

Teacher-Directed Method

The students, upon entering the classroom, were directed to open their textbooks to the appropriate page. The introduction to the experiment was then read and from this the teacher would extract the purpose for the present experiment. Students would copy the purpose into their notebooks. The teacher would then provide students with the required apparatus for the experiment and students, working in pairs, would perform the experiment by following the procedures in the texts. Students were required to answer all questions in boldface type in the procedures of the text. Once this was done, students would write a conclusion to the purpose of the experiment and answer the questions in the text at the end of the experimental procedure.

During the time the students were doing the experiment the teacher would circulate through the room to observe the students' progress and to assist students who needed help.

Self-Paced Method

The students, upon entering the classroom, would continue their work from where they had left it at the end of the last period. If they were about to start an experiment they would follow these steps.

Step 1 - Read the objectives for the sequence they were working on from the back of the package of optics and copy these objectives into the laboratory write up.

Step 2 - Assemble the required apparatus as given in the text.[1] They had been instructed as to where in the room the apparatus was kept, so only in exceptional cases did they need assistance at this point.

Step 3 - The students proceeded with the experiment, either alone or with the help of a laboratory partner, as instructed by the text and answered the questions in boldface type that are in the procedures.

Step 4 - Once the experimental phase of the experiment was complete students would write out what they had learned about the objectives and answer the questions at the end of the procedure in the text.

While the students were working on the experiment the teacher would circulate through the room making sure to speak to each student and observe

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1. Introducing Science Concepts in the Laboratory. M.C. Schmid, 1973.

Teacher-Directed Method	Self-Paced Method
	their progress with their work. If any problems had been encountered by the student these would be discussed and a solution found. The teacher attempted to speak to each student twice each period, once at the beginning of the period and again at the end of the period. Any student could receive the assistance of the teacher at any time during the period.

HOW LIGHT TRAVELS

Instructions:

1. All answers must be written on an answer sheet - do not mark this paper.

2. At the end of the exam you must return both question sheets and answer sheets.

3. You may use pencil and ruler for diagrams but all written answers must be in pen.

PART A: True or False. On the answer sheet place an X on T if the statement is true, and on F if false.

1. You can see light energy.

2. Vision results from signals sent out from the eyes.

3. Isaac Newton experimented with light.

4. Incandescent means "cold light".

5. No plant or animal will emit light unless oxygen is present.

6. Fireflies are an example of bioluminescent light sources.

7. Shadows decrease in size as object moves closer to the screen.

8. The pinhole image of a candle flame is an erect candle flame.

9. As an object moves closer to a candle flame the umbra increases and the penumbra decreases in size.

10. Aluminum foil is an example of a translucent object.

11. Light energy from a source is visible in the space between the source and the screen.

12. A candle flame is an example of a broad source of light.

13. A candle flame is an example of a luminous source of light.

14. When we hold a card with a pinhole between a candle flame and a screen, we see an inverted shadow of a candle flame.

PART B: Completion. Write on the answer sheet the best word or phrase which best completes each of the following statements:

1. For your eyes to receive information from an object the object must reflect ____.

2. An object which emits its own light is called ____.

3. The narrowest possible beam of light is called ____.

4. An object through which no light will pass is called ____.

5. When a light source looks small, either because it is small or because it is far away, it is called ___.

6. A frosted light bulb as seen from within the room is called ____.

7. The edges of shadows cast by a tiny light source are ____.

8. The edges of shadows cast by large light sources are ____.

9. Shadows are good evidence that light travels in ____.

10. If most of the light passes through the object, the object is said to be ____.

11. During an eclipse of the sun, the area of partial shadow on earth is called the ____.

12. The area of complete shadow is called ____.

13. We study light because light is an important means of ____.

14. A light source we use in class made of a transformer, small light bulb, double convex lens and a baffle is called ____.

15. Describe fully what you see on screen when you hold a spherical opaque ball between a point light source and a screen. The ball is near the screen. (3 marks)

A P P E N D I X B

ITEM ANALYSIS OF ACHIEVEMENT TEST

Test	Post		Retention	
Item	Difficulty Index	Discrimination Index	Difficulty Index	Discrimination Index
1	.932	0.34	.973	0.14
2	.865	0.40	.892	0.24
3	.392	0.43	.405	0.39
4	.459	-0.04	.514	-0.07
5	.946	0.18	.919	0.01
6	.838	0.33	.824	0.41
7	.351	0.19	.230	0.16
8	.541	0.21	.622	0.09
9	.365	0.21	.284	0.29
10	.811	0.30	.784	0.32
11	.703	0.21	.608	0.28
12	.527	0.35	.405	0.33
13	.297	0.04	.230	0.09
14	.716	0.40	.797	0.30
15	.365	0.26	.446	0.12
16	.689	0.30	.730	0.19
17	.716	0.30	.676	0.31
18	.432	0.09	.568	0.10
19	.149	-0.03	.162	-0.20
20	.892	0.24	.905	0.35
21	.716	0.16	.824	0.09
22	.095	0.13	.081	0.18
23	.649	0.33	.581	0.25
24	.824	0.31	.784	0.24
25	.432	0.43	.500	0.31
26	.365	0.45	.203	0.24
27	.446	0.14	.203	0.26
28	.784	0.15	.838	0.13
29	.811	0.23	.851	0.18
30	.676	0.43	.541	0.18
31	.230	0.40	.270	0.56
32	.311	0.29	.230	0.24
33	.608	0.55	.514	0.52
34	.608	0.42	.405	0.29
35	.676	0.44	.554	0.22
36	.405	0.59	.311	0.57
37	.541	0.50	.486	0.41
38	.608	0.58	.459	0.55
39	.392	0.50	.243	0.51
40	.622	0.35	.514	0.21
41	.405	0.20	.432	0.09
42	.568	0.42	.635	0.30
43	.608	0.28	.527	0.33

Test	Post		Retention	
Item	Difficulty Index	Discrimination Index	Difficulty Index	Discrimination Index
44	.270	0.27	.189	0.19
45	.541	0.59	.500	0.53
46	.216	0.18	.216	0.24
47	.095	0.07	.176	-0.07
48	.351	0.08	.284	0.10
49	.500	0.41	.568	0.31
50	.581	0.37	.689	0.37
51	.635	0.42	.649	0.42
52	.527	0.57	.459	0.58
53	.419	0.13	.257	0.29
54	.405	0.36	.419	0.39
55	.689	0.36	.743	0.36
56	.905	0.19	.905	0.24
57	.295	0.06	.338	0.10
58	.405	-0.10	.176	-0.07
59	.541	0.39	.635	0.19

ITEM-TEST CORRELATIONS FOR THE ATTITUDE SCALES

	Experimenting		Independent Investigation	
Item	Pre	Post	Pre	Post
1	-0.045	0.283	0.271	0.385
2	0.257	0.229	0.252	0.416
3	0.457	0.618	0.467	0.426
4	0.025	0.126	0.581	0.654
5	0.360	0.494	0.140	0.498
6	0.406	0.598	0.112	0.479
7	0.346	0.301	0.204	0.353
8	0.232	0.480	0.210	0.504
9	0.304	0.558	0.385	0.563
10	0.192	0.293	0.218	0.454
11	0.261	0.569	0.515	0.434
12	0.112	0.487	0.454	0.517
13	0.207	-0.036	0.307	0.497
14	0.090	0.556	0.422	0.460
15	0.291	0.619	0.294	0.196
16	0.330	0.511	0.166	0.459
17	0.335	0.471	0.259	0.505
18	0.471	0.658	0.268	0.347
19	0.331	0.637	0.080	0.387
20	0.229	0.342	0.199	0.083

ITEM ANALYSIS OF ATTITUDE SCALES

ATTITUDE SCALE - EXPERIMENTING

	Pre-test		Post-test	
Item	Mean	Standard Deviation	Mean	Standard Deviation
1	2.446	1.346	1.892	1.001
2	3.514	1.316	3.230	1.267
3	1.459	0.863	1.608	0.991
4	2.500	1.464	1.986	1.104
5	2.649	1.521	2.514	1.436
6	2.054	1.084	2.122	1.110
7	1.676	1.148	1.716	1.014
8	2.203	1.570	2.243	1.524
9	2.108	1.340	1.973	1.238
10	1.959	1.349	1.730	1.064
11	2.000	1.228	2.230	1.234
12	2.527	1.510	2.919	1.301
13	2.446	1.416	2.514	1.367
14	2.770	1.400	2.716	1.531
15	1.973	1.282	2.311	1.181
16	3.257	1.536	2.784	1.528
17	2.770	1.400	2.865	1.368
18	2.041	1.349	2.378	1.290
19	2.324	1.229	2.446	1.124
20	2.703	1.602	2.176	1.243
	$\bar{x}$ = 47.38	= 10.11	$\bar{x}$ = 46.35	= 12.87

ATTITUDE SCALE - INDEPENDENT INVESTIGATION

	Pre-test		Post-test	
Item	Mean	Standard Deviation	Mean	Standard Deviation
1	2.081	1.301	2.095	1.184
2	2.324	1.294	2.541	1.326
3	3.203	1.499	3.324	1.481
4	2.419	1.562	2.459	1.397
5	2.784	1.599	2.932	1.446
6	2.392	1.515	2.257	1.272
7	3.784	1.274	3.730	1.306
8	3.068	1.456	3.027	1.385
9	3.905	1.229	3.270	1.242
10	1.865	1.348	2.311	1.271
11	2.257	1.366	2.243	1.203
12	2.324	1.481	2.216	1.436
13	1.865	1.253	2.081	1.301
14	3.203	1.535	3.257	1.462
15	2.676	1.536	2.595	1.404
16	1.986	1.188	2.446	1.229
17	2.541	1.387	2.662	1.388
18	3.068	1.275	3.149	1.279
19	2.122	1.260	2.743	1.283
20	4.405	1.084	3.959	1.199
	$\bar{x}$ = 54.27	= 11.09	$\bar{x}$ = 55.30	= 13.52

SCIENCE 8

OPTICS

Name_____

Circle the answer of your choice.

1. Light travels
   a) in straight lines
   b) in circular motion
   c) through all solids
   d) through all liquids
   e) none of these

2. A body which gives off its own light is
   a) translucent
   b) opaque
   c) cold
   d) luminous
   e) none of these

3. An example of a non-luminous body is
   a) the sun
   b) a candle
   c) the moon
   d) a star
   e) none of these

4. Material which allows most of the light to pass through is
   a) opaque
   b) translucent
   c) transparent
   d) incandescent
   e) cold

5. Light that bounces off a surface is said to be
   a) reflected
   b) diffused
   c) converged
   d) diverged
   e) absorbed

6. Wax paper is probably
   a) transparent
   b) translucent
   c) opaque
   d) none of these
   e) all of these

7. An incandescent object is one that
   a) gives off cold light
   b) is hot enough to give off light
   c) does not give off any light
   d) none of these

8. The shadow formed from a pencil and a small source is sharpest when
   a) the pencil is close to the screen
   b) the pencil is halfway between the source and the screen
   c) the pencil is close to the source
   d) none of these

9. When you move away from a light source the light appears dimmer because
   a) less light is emitted
   b) the light bends away from you
   c) the light stops before it gets to you
   d) none of these

10. Bioluminescence is
    a) a type of bacteria
    b) light from a living source
    c) a type of algae
    d) none of these

11. The penumbra is
    a) a full shadow
    b) a source of light
    c) a partial shadow
    d) none of these

12. When light goes from a more dense to a less dense medium it is
    a) bent away from the normal
    b) goes straight through
    c) bent toward the normal
    d) none of these

13. Parallel rays reflected from a concave mirror form
    a) an upside down image
    b) a point image
    c) a right side up image
    d) none of these

14. A concave mirror is
    a) dished inwards
    b) dished outwards
    c) a flat surface
    d) none of these

15. A normal line is
    a) horizontal to the surface
    b) at 45° to the survace
    c) perpendicular to the surface
    d) none of these

16. The focal point of a concave mirror is
    a) the point where the reflected rays cross
    b) the center of the curved surface
    c) the center of the circle which the mirror is part
    d) none of these

17. A double convex lens has
    a) both sides dished outwards
    b) both sides dished inwards
    c) one side dished inwards and the other side dished outwards
    d) none of these

18. When parallel light rays strike a concave lens
    a) they diverge outward
    b) they are reflected
    c) they converge at a point
    d) none of these

19. A double convex lens, forms at the focal point
    a) a real image, larger than the object
    b) a virtual image
    c) a point of light
    d) none of these

20. A transparent object
    a) lets some light through it
    b) lets all the light through it
    c) does not allow light to pass through it
    d) none of these

21. A solar eclipse happens every time
    a) the moon is between the sun and earth
    b) the earth stops light from hitting the moon
    c) the moon stops some sunlight from reaching the earth
    d) none of these

22. A shadow is a
    a) absence of light
    b) area where light is blocked out
    c) where light shines
    d) none of these

23. A broad light source can produce a
    a) sharp shadow
    b) fuzzy shadow
    c) no shadow
    d) none of these

24. An example of a broad luminous light source is
    a) the moon b) the sun c) a star d) none of these

25. An example of a non luminous light source is
    a) the moon b) the sun c) a star d) none of these

26. The image in a plane mirror is
    a) only inverted vertically
    b) only inverted laterally
    c) inverted vertically and laterally
    d) not inverted vertically or laterally

27. In a plane mirror, the image is
    a) real
    b) not real or virtual
    c) virtual
    d) real and virtual

28. In a plane mirror, the image is
    a) higher than the object
    b) smaller than the object
    c) higher or smaller than the object
    d) same height as the object

29. In a plane mirror, the image is
    a) thinner than the object
    b) wider than the object
    c) thinner or wider than the object
    d) same width as the object

30. In a plane mirror, the image appears to be
    a) farther behind the mirror than the object
    b) closer to the mirror than the object
    c) farther or closer to the mirror than the object
    d) same distance from the mirror as the object

31. In a plane mirror, the image <u>really</u> is
    a) behind the mirror
    b) in front of the mirror
    c) on the back of the mirror
    d) further behind the mirror than the object is in front

32. A line joining the object and the image in a plane mirror is
    a) perpendicular to the normal line
    b) perpendicular to the back of the mirror
    c) perpendicular to the incident ray
    d) perpendicular to the reflected ray

33. The ray of light striking the mirror is called
    a) incident ray
    b) reflected ray
    c) normal ray
    d) horizontal ray

34. The angle of incidence is the angle between
    a) the incident ray and the parallel mirror ray
    b) the incident ray and the reflect ray
    c) the incident ray and the normal line
    d) the incident ray and the perpendicular ray

35. The angle of incidence is
    a) larger than the angle of reflection
    b) smaller than the angle of reflection
    c) equal to the angle of reflection
    d) slightly smaller or larger than the angle of reflection

36. If a ray of light travels towards a mirror along the path of a reflected ray, the ray will
    a) leave the mirror along the path of the incident ray
    b) leave the mirror along the path of the normal line
    c) leave the mirror along the path of the reflected ray
    d) leave the mirror along a path parallel to the reflected ray

37. Parallel light rays reflect off a plane mirror
    a) as parallel light rays
    b) as diffused light rays
    c) as converging light rays
    d) as diverging light rays

38. When the angle of reflection is 30^{o}, the angle of incidence must be
    a) 45^{o} b) 60^{o} c) 30^{o} d) 90^{o}

39. In the diagram, ray BC is
    a) an incident ray
    b) a diffused ray
    c) a converging ray
    d) a diverging ray
    e) none of these

40. The point at which a lens causes light rays to meet is said to be
    a) a principal axis
    b) a principal focus
    c) a diffused spot
    d) a sharp image
    e) none of these

41. The purpose of a lens is to
    a) reflect light
    b) refract light
    c) screen colour
    d) diffuse light
    e) none of these

42. An image you see in a plane mirror is
    a) erect
    b) inverted
    c) diffused
    d) refracted
    e) none of these

43. An image which can be reflected on a screen is
    a) virtual
    b) real
    c) diverging
    d) converging
    e) transparent

44. The image produced by the paper A is
    a) inverted
    b) erect
    c) real
    d) a and c
    e) b and c

45. Parallel light rays reflect off a plane mirror
    a) as parallel light rays
    b) as diffused light rays
    c) as converging light rays
    d) as diverging light rays

46. A real image is
    a) formed by a convex mirror
    b) formed by a plane mirror
    c) always upside down
    d) none of these

47. The angle of refraction is
    a) always equal to the angle of incidence
    b) always less than the angle of incidence
    c) always more than the angle of incidence
    d) none of these

48. The principal axis
    a) is where the reflected rays meet
    b) passes through the focal point
    c) is perpendicular to the normal
    d) none of these

49. When a light ray is refracted it is
    a) bent
    b) divided
    c) reflected
    d) none of these

50. A lens that is wider at the center than at the edge is known as
    a) concave
    b) convex
    c) concave-convex
    d) none of these
    e) all of a, b, and c

51. This is a diagram of a
    a) convex lens
    b) concave lens
    c) plane mirror
    d) umbra
    e) penumbra

52. In this plane mirror ray AB is
    a) an incident ray
    b) a diffused ray
    c) a converging ray
    d) a diverging ray
    e) a perpendicular

53. In a plane mirror the angle of incidence is
    a) not equal to the angle of reflection
    b) equal to the angle of refraction
    c) equal to the angle of reflection
    d) none of these

54. A virtual image is
    a) formed by a plane mirror
    b) cannot be put on a screen
    c) upside down
    d) none of these

55. You cannot see around corners because
    a) your eyes are not equipped for this
    b) light travels in straight lines
    c) objects around a corner do not reflect light
    d) none of these

56. A luminous object is one that
    a) gives off light
    b) reflects light
    c) does not reflect light
    d) none of these

57. In a plane mirror the fewest number of sightlines needed to determine the position of the image is
    a) 1 b) 2 c) 3 d) more than 3

58. In a plane mirror the image is
    a) the same size as the object
    b) smaller than the object
    c) bigger than the object
    d) depends on the distance from the mirror

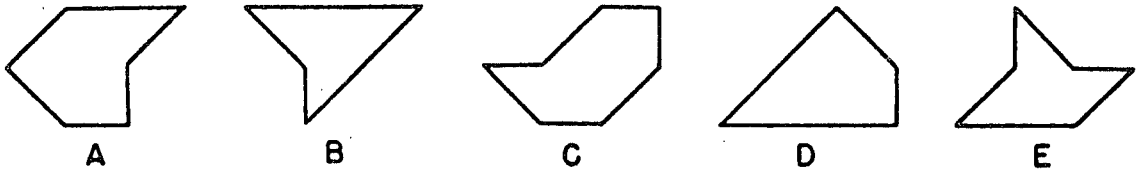
59. An image in a mirror is laterally inverted when
    a) its left side appears to be the right side of the image
    b) the image is upside down
    c) image can be put on a screen
    d) none of these

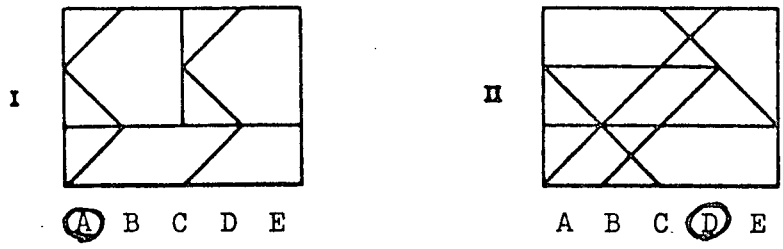
HIDDEN FIGURES TEST

This is a test of your ability to tell which one of five simple shapes can be found in a more complex pattern. At the top of each page in this test are five simple shapes lettered A, B, C, D, and E. Beneath each row of shapes is a page of patterns. Each pattern has a row of letters beneath it. The correct answer is shown by a circle around the letter of the shape of the shape which you are to find in the pattern. When you have found the shape of the pattern, use the pencil supplied to outline it as shown in the examples below.

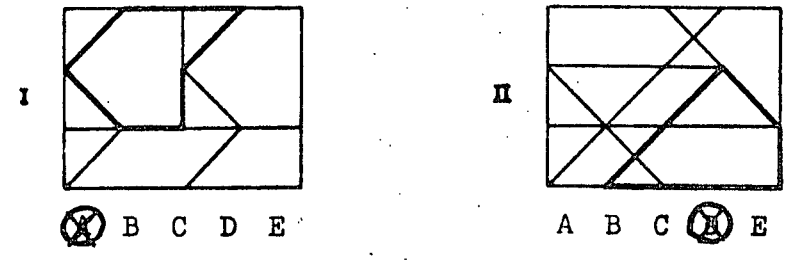
NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

Now try these 2 examples.





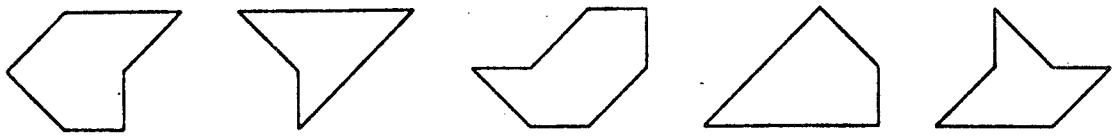
The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

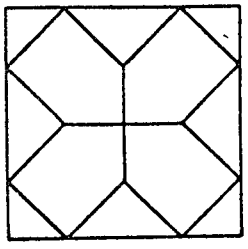


You will have 10 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

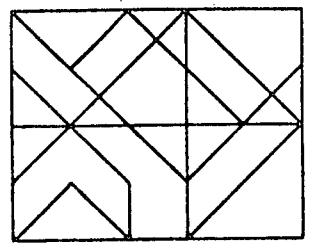
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Part 1 (10 minutes)

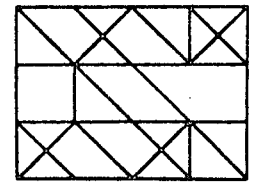


1. 

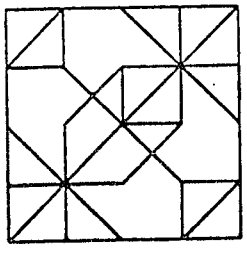
(A) B C D E

2. 

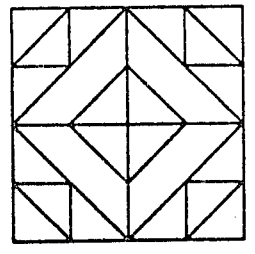
A (B) C D E

3. 

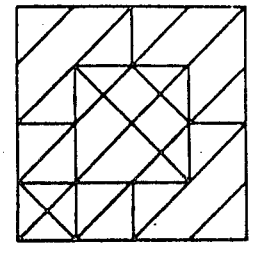
A B C D (E)

4. 

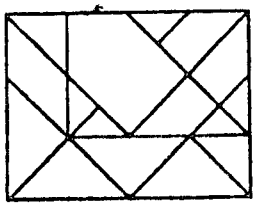
A B C (D) E

5. 

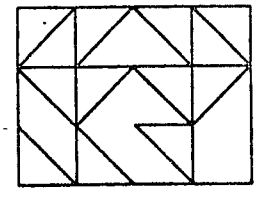
A (B) C D E

6. 

A B C (D) E

7. 

A B C D (E)

8. 

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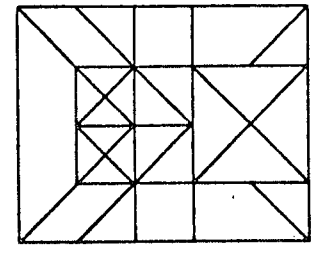
9. 

A (B) C D E

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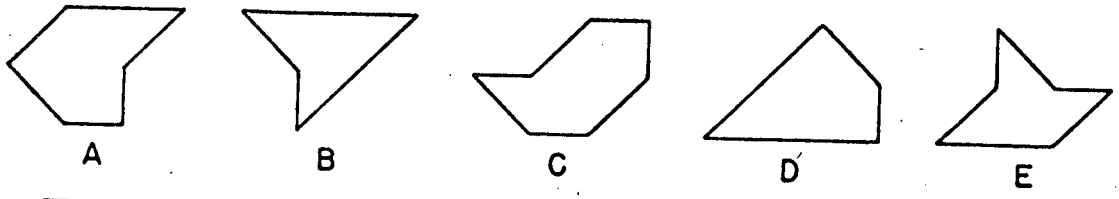
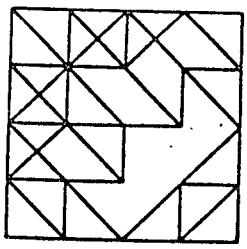
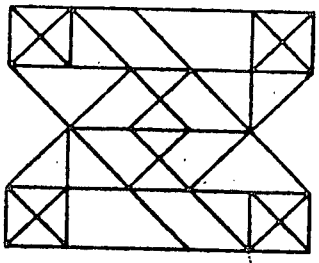
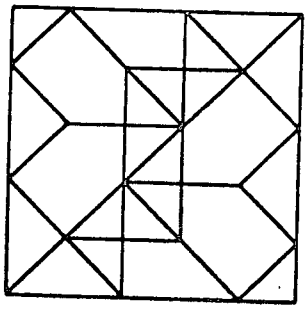


10. 

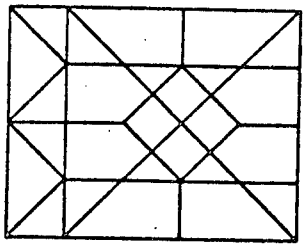
A B C (D) E

11. 

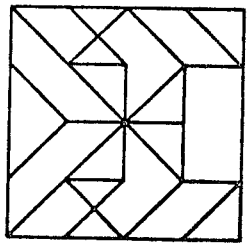
A B (C) D E

12. 

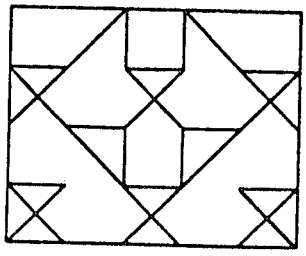
(A) B C D E

13. 

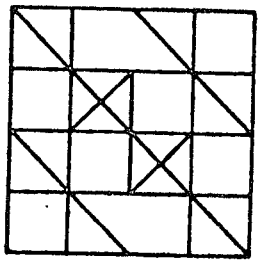
A B C D (E)

14. 

A B C D (E)

15. 

A B (C) D E

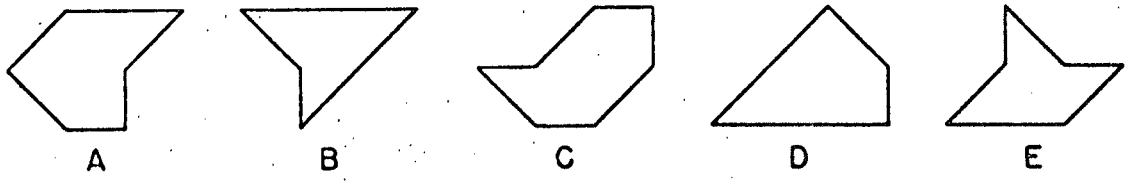
16. 

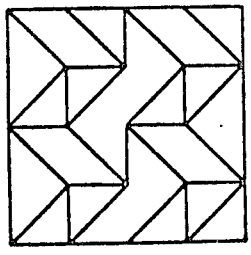
A B (C) D E

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

STOP.

Part 2 (10 minutes)



17. 

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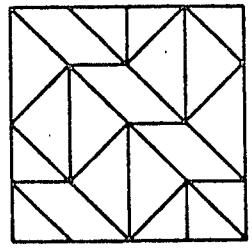
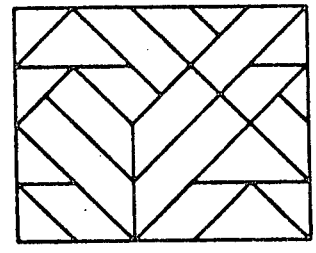
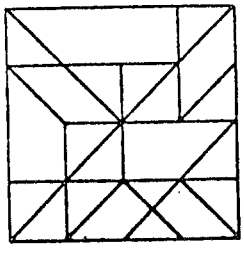
18. 

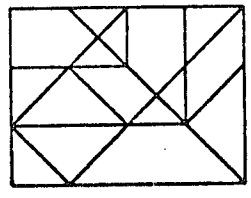
A B (C) D E

19. 

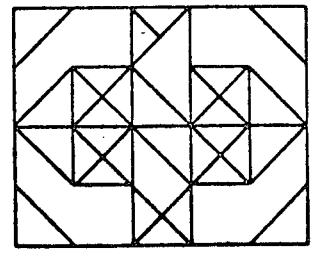
A B C (D) E

20. 

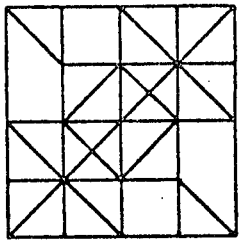
A (B) C D E

21. 

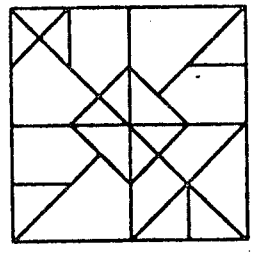
(A) B C D E

22. 

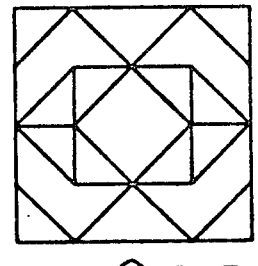
A (B) C D E

23. 

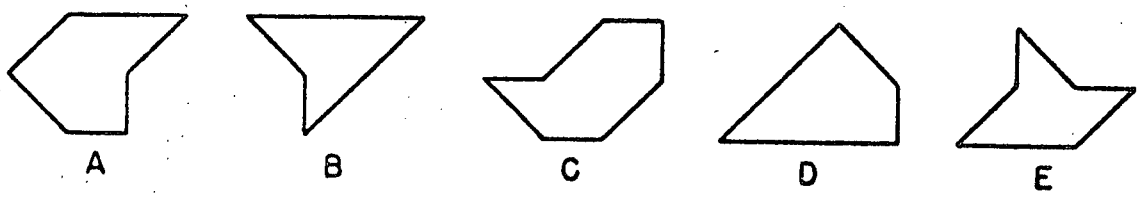
A B (C) D E

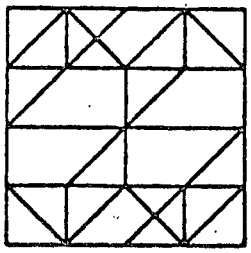
24. 

A (B) C D E

25. 

A B (C) D E



26. 

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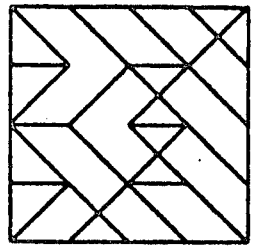
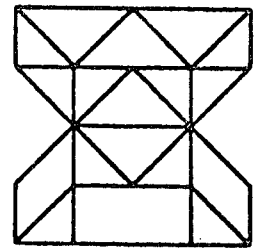
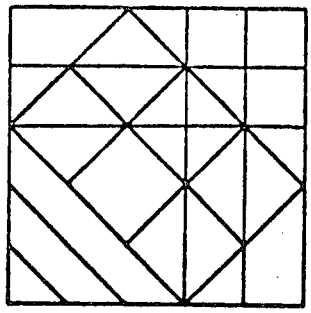
27. 

A B C (D) E

28. 

(A) B C D E

29. 

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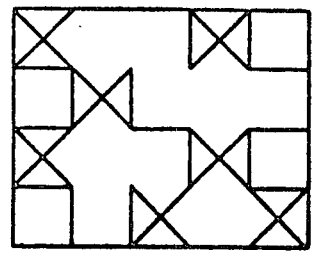
30. 

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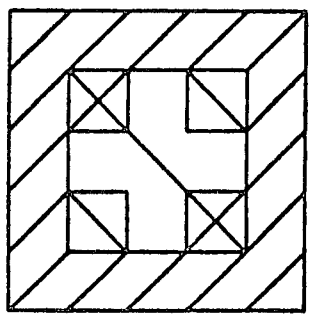
31. 

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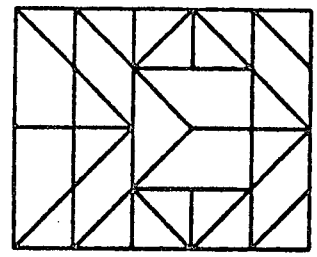
32. 

(A) B C D E

DO NOT GO BACK TO PART 1, AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.

The modified version of the Test of Science Processes as used by Mott (1974) was also used in this study. The table below indicates the item numbers on both the modified and original tests.

Test of Science Processes

Modified Item No.	Original Item No.	Modified Item No.	Original Item No.
1	13	26	59
2	15	27	60
3	18	28	63
4	19	29	64
5	20	30	71
6	21	31	72
7	22	32	73
8	24	33	74
9	26	34	75
10	27	35	77
11	32	36	82
12	33	37	83
13	35	38	85
14	36	39	87
15	38	40	88
16	39	41	89
17	40	42	90
18	41	43	91
19	44	44	92
20	48	45	94
21	51	46	37
22	55	47	45
23	56	48	79
24	57	49	80
25	58	50	81

DO NOT TURN THE PAGE UNTIL THE TEACHER TELLS YOU TO DO SO

TEST OF SCIENCE PROCESSES

INSTRUCTIONS

This test is called the Test of Science Processes. "Processes" are ways of doing things. For example, scientists have to be able to look at things very carefully and tell what they see. Scientists have to be able to measure and use numbers. And scientists have to be able to plan and understand experiments. This is a test of how well YOU can do some of the things scientists have to do. It is NOT a test of how many facts you know about science.

You should have a pencil, an answer sheet, a piece of scrap paper for doing any figuring, and this test booklet. If you do not have any of these things, raise your hand and the teacher will get what you need. PLEASE DO NOT WRITE IN THE TEST BOOKLET.

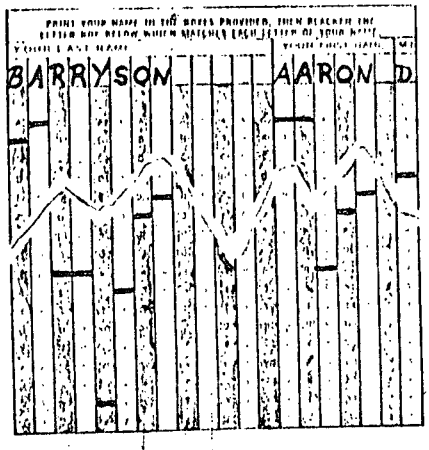
Now look at the picture of the answer sheet below. It shows the only right way to fill in answers. Only numbers 146 to 150 are filled in correctly. You must use a pencil and you must make your answers black and they must fill the box completely and not overflow. Do NOT make any of the mistakes shown in numbers 151 to 155. Do NOT make an "X." Do NOT make your answers too light. Do NOT miss the box. Do NOT circle the answer or make a check mark. Erase your mistakes completely. There is only one right way to fill in your answers -- COMPLETELY AND BLACKLY WITH A PENCIL. Do NOT wrinkle your answer sheet. It is going to be read by a machine and the machine can not read wrinkled papers. The machine can only read penciled answers so DO NOT USE INK.

Now look at your answer sheet. Find where it says "GRADE." It is next to where some of the numbers are already blackened in. Now blacken in the number that tells which grade you are in. Now print your name in the correct boxes and blacken in the letter boxes under each letter in your name. Look at the way it is done in the picture of the answer sheet on this page. Be very careful to blacken the right letter boxes.

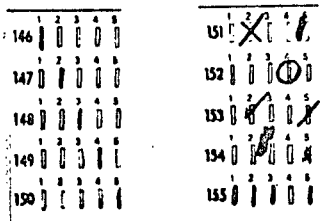
Most of the questions on this test have pictures that go with them. The first few are in color. The teacher will show you the color pictures and read the questions WITH you. Then you will have about half a minute to think about the question and mark your answer. Always be careful to mark your answer in the right place on your answer sheet. If you make a mistake or change your mind, be sure to erase the wrong answer completely and then mark your new answer. NEVER mark more than one answer for each question. Be sure to keep up with the teacher. If you can not think of an answer, either guess or skip it. Do not spend too much time on any one question. If you have difficulty with a question, go on to the next one and come back to the hard one later. Every so often, the teacher will tell you about which question you should be working on. PLEASE DO NOT WRITE IN THE TEST BOOKLET. If you need to do any figuring, you may do it on the scrap paper.

IF YOU HAVE ANY QUESTIONS, RAISE YOUR HAND NOW.

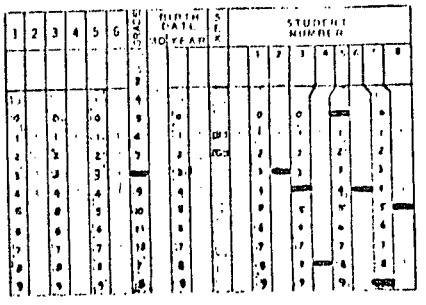
SAMPLE NAME GRID



SAMPLE ANSWERS



SAMPLE GRADE AND NUMBER



DO NOT TURN THE PAGE UNTIL THE TEACHER TELLS YOU TO DO SO

DO NOT WRITE IN THE TEST BOOKLET

ALL OF THE QUESTIONS ON THIS PAGE REFER TO COLOR PICTURES. YOU SHOULD LOOK AT THE PICTURES AS THE TEACHER SHOWS THEM TO YOU AND THEN ANSWER THE QUESTIONS.

1.
BE SURE YOU ARE USING ANSWER SPACE 1
This is a picture of 5 shirts. Which choice includes only the shirts you would wear if you wanted to be seen easily in the dark?

1. 1 and 4
2. 2 and 3
3. 1, 3, and 5
4. 2, 4, and 5
5. 2, 3, and 5

2.
This is a picture of 8 pieces of paper. Which is the only group of two pieces that you can take away so that you have taken away all of one color and all of one shape?

1. 1 and 6
2. 2 and 8
3. 2 and 7
4. 1 and 3
5. 4 and 5

3.
This is a picture of 5 objects. Which choice is a way they are the same?

1. They are all used for eating.
2. They are all the same color.
3. They are all made of wood.
4. They are all about the same size.
5. They are all about the same shape.

4.
This is a picture of 8 pieces of paper. Which choice includes only the pieces which are red and have a triangular hole?

1. 1, 4, and 6
2. 1, 2, 3, 4, and 6
3. 5 and 8
4. 1, 4, 6, and 8
5. 4 and 6

5.
BE SURE YOU ARE USING ANSWER SPACE 5
Look at the picture of the 8 pieces of paper again. Which choice includes only those pieces that are NOT red and have square holes?

1. 2, 3, 5, and 7
2. 5 and 7
3. 5, 7, and 8
4. 1, 3, 5, 7, and 8
5. 2, 3, 4, and 8

6.
This is a picture of 10 beads. Which is the only group of 3 beads that you can take away so that your three are all one color and none of the 7 you leave is that color?

1. 4, 6, and 7
2. 2, 6, and 8
3. 1, 3, and 5
4. 3, 5, and 10
5. 4, 7, and 9

7.
This is a picture of 5 pieces of paper that are slightly different. Which choice tells exactly how they are different?

1. 4 is a different color.
2. 2 is smaller.
3. 2 is smaller than all the others and 4 is a different color.
4. 1, 3, 4, and 5 are the same size.
5. 4 and 2 are different from each other.

8.
This is a picture of some cut flowers. They are called Anthurium. The red parts are called bracts. Just from what you see in the picture, which of the following statements can you make?

1. Anthurium have either red or white bracts and green leaves.
2. All Anthurium have red bracts and green leaves.
3. All Anthurium have green leaves.
4. Anthurium bracts may be red, or white, or any color in between, but the leaves are always green.
5. None of these, because you do not have enough information.

9.
This is a picture of 8 pieces of paper. If you group them by color, what is the smallest number of groups you can make?

1. 1
2. 2
3. 3
4. 4
5. 5

10.
BE SURE YOU ARE USING ANSWER SPACE 10
Look at the picture of 8 pieces of paper again. If you group them by shape, what is the smallest number of groups you can make?

1. 1
2. 2
3. 3
4. 4
5. 5

11.
This is a picture of 7 toy cars. Cars 1, 2, 4, and 6 make up a special group. This group is special because it includes all the cars that

1. have wheels.
2. are not blue and have wheels.
3. are red.
4. are not blue.
5. are red and white.

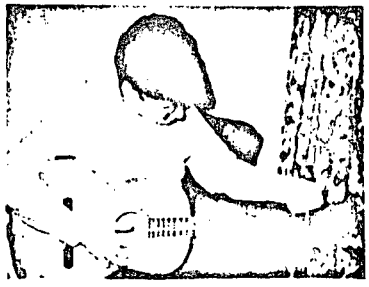
12.
This is a picture of pieces of paper which were left in the sun for different numbers of days. Which is the only thing you can say for sure, based on what you see in the picture?

1. Blue paper fades more than red paper.
2. All paper will continue to fade forever the longer you leave it in the sun.
3. Any paper left in the sun will fade.
4. This paper faded more by day 5 than it had by day 2.
5. Paper will fade in the sun, but cloth will not.

GO ON TO PAGE 3

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN LOOK AT THINGS AND HOW CAREFULLY YOU CAN TELL WHAT YOU SEE.

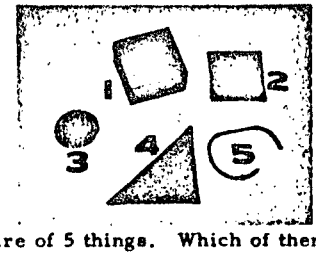
13.



This is a picture of a boy studying what happens when he tightens or loosens the strings of a guitar. Which one of the following is most important to his study?

1. The lengths and thicknesses of the strings
2. The size of the guitar
3. The temperature of the strings
4. What the guitar and strings are made of
5. The age of the guitar

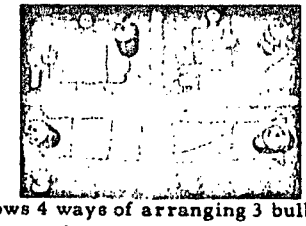
14.



This is a picture of 5 things. Which of them has volume?

1. The block
2. The square
3. The circle
4. The triangle
5. The curved line

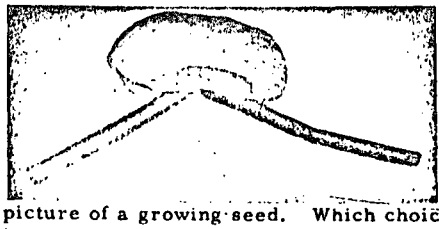
15.



This picture shows 4 ways of arranging 3 bulbs and a battery. Which two ways are the same?

1. 1 and 4
2. 2 and 4
3. 1 and 2
4. 3 and 2
5. 3 and 4

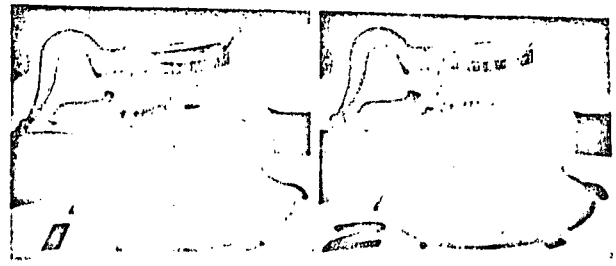
16.



This is a picture of a growing seed. Which choice best describes what you see?

1. The seed is growing.
2. Someone planted and watered the seed.
3. The seed coat has split and a root and a stem are coming out of the seed.
4. A root is growing down and a stem is growing up.
5. The seed has germinated.

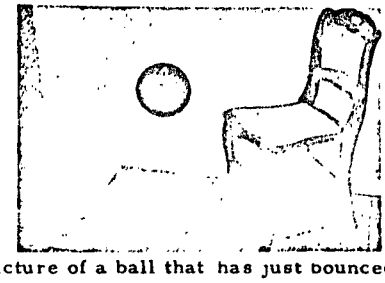
17.



These are two pictures of a pot of water on a stove. Picture 2 was taken 5 minutes after picture 1. Which choice is the best way of telling that there has been a change?

1. The water is boiling in picture 2.
2. The gas is on in picture 2.
3. The water gets hot when the gas is on.
4. The water is not boiling in picture 1.
5. The water is boiling in picture 2, but it is not boiling in picture 1.

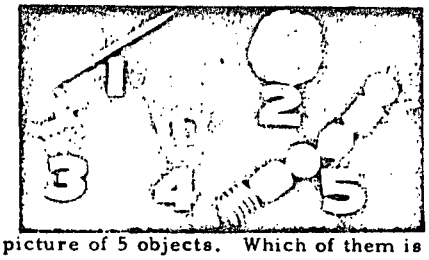
18.



This is a picture of a ball that has just bounced off the wall and will bounce on the floor. Which one of the following is LEAST important to someone studying the bouncing?

1. What the ball is made of
2. What the floor is made of
3. What the wall is made of
4. How high the wall is
5. Gravity

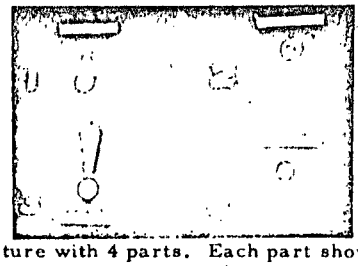
19.



This is a picture of 5 objects. Which of them is NOT in the same phase of matter (solid, liquid, gas) as all the others?

1. The pencil
2. The water
3. The toy giraffe
4. The glass
5. The beads

20.



This is a picture with 4 parts. Each part shows a compas a bar magnet, and a horseshoe magnet. In which two pai are the three things arranged in the same way?

1. 1 and 3
2. 2 and 4
3. 1 and 4
4. 2 and 3
5. 1 and 2

BE SURE YOU ARE USIN ANSWER SPACE 20

GO ON TO PAGE

DO NOT WRITE IN THE TEST BOOKLET

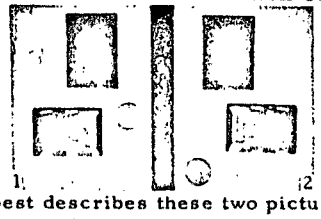
21.

This is a picture of a match. Which choice tells all that you can see in the picture and no more?

1. Someone is holding a match which is burning and giving off smoke.
2. Someone has just lit a match.
3. Someone is holding a burning match.
4. Someone is about to be burned by the match he is holding.
5. A match is burning and giving off light and heat.

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN TELL HOW THINGS ARE THE SAME OR DIFFERENT.

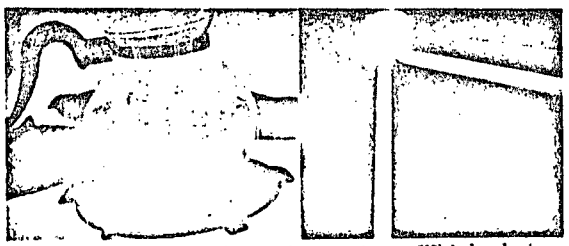
22.



Which choice best describes these two pictures?

1. Different things are in both pictures, and they are arranged differently.
2. Different things are in both pictures, but they are arranged in the same way.
3. The same things are in both pictures, but they are arranged differently.
4. The same things are in both pictures, and they are arranged in the same way.
5. Picture 2 is a mirror image of picture 1.

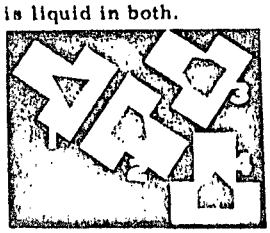
23.



This is a picture of two things happening. Which choice is a way they are the same?

1. Something is burning in both and heating something else.
2. Glass is used in both.
3. There is a solid burning in both.
4. Something is cooking in one, but in the other something is being lit.
5. There is liquid in both.

24.

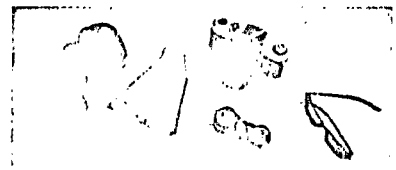


This is a picture of 4 objects. Which are the same?

1. 1 and 4
2. 2 and 3
3. 1, 2, and 4
4. None
5. 2 and 4

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN PUT THINGS INTO GROUPS.

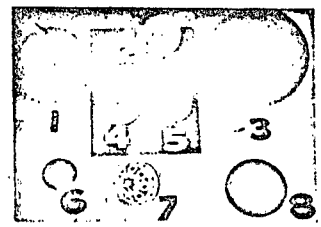
25.



This is a picture of 5 objects that are alike in one special way. How are they alike?

1. They are all the same shape.
2. They all help you see things that are far away.
3. They are all made of metal.
4. They all have lenses.
5. They all make things look smaller.

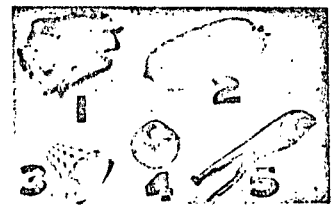
26.



This is a picture of 8 objects. Which choice includes all the objects that are round like a ball and NONE of the objects that are flat?

1. 1, 2, 3, 4, 5, 7, and 8
2. 2, 3, 5, 7, and 8
3. 4, 6, and 8
4. 2, 3, and 5
5. 1, 2, 3, 5, and 7

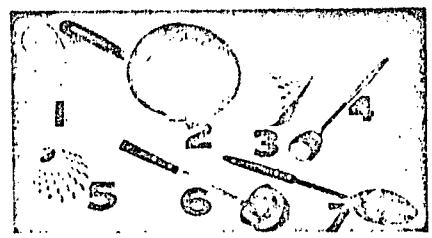
27.



This is a picture of 5 objects. Which choice includes only those that would make good paper weights?

1. 1, 3, 4, and 5
2. 3 and 4
3. 1, 2, and 5
4. 1 and 5
5. 1, 4, and 5

28.



This is a picture of 7 objects. Which choice includes only those that can be used for carrying more than just a few drops of water?

1. 1, 2, 3, 6, and 7
2. 1, 2, 3, 4, and 6
3. 1, 2, 3, 4, 5, and 6
4. 1, 2, 3, 4, 6, and 7
5. 1, 2, 3, and 6

GO ON TO PAGE 5

29.

This is a picture of 10 marbles and 6 other objects. Which choice includes only those that can be used to carry all 10 marbles at the same time?

1. 1, 3, and 6
2. 1 and 3
3. 1, 3, and 5
4. 1, 2, and 3
5. 2, 3, 4, and 5

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN USE NUMBERS.

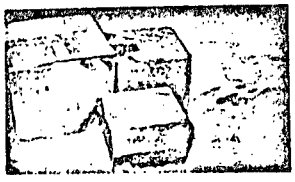
30.

BE SURE YOU ARE USING ANSWER SPACE 30

Which number below is five hundred sixteen thousand, three hundred seventy-two?

1. 516,312
2. 572,316
3. 516,372
4. 372,516
5. 516,370

31.



Here is a picture of 4 blocks. Which choice lists the blocks from smallest to biggest?

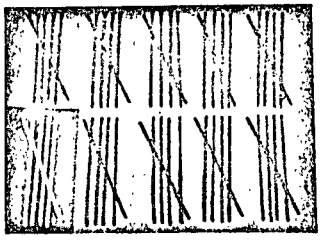
1. 1, 4, 3, 2
2. 2, 4, 3, 1
3. 2, 3, 1, 4
4. 2, 3, 4, 1
5. 3, 2, 4, 1

32.

Which one of these temperature readings is 25 degrees lower than 15°F?

1. -10°F
2. 15°F
3. -25°F
4. 0°F
5. 40°F

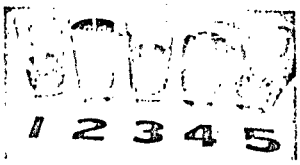
33.



This picture shows 50 straws. What fraction of the straws are on the dark paper?

1. 1/5
2. 50/5
3. 10/25
4. 2/50
5. 1/10

34.



This is a picture of 5 glasses of colored water. Which choice lists the glasses from most water to least water?

1. 5, 3, 1, 4, 2
2. 2, 4, 3, 5, 1
3. 5, 4, 3, 2, 1
4. 4, 2, 3, 1, 5
5. 2, 4, 3, 1, 5

35.

Which one of these decimals is equal to 15/100?

1. .0015
2. .015
3. 15.0
4. 1.5
5. .15

36.

If the 17th of March is Monday, what day of the week is the 23rd of March?

1. Sunday
2. Monday
3. Tuesday
4. Thursday
5. Friday

37.

If there are 25 children in a class and 5 are absent, what percent of the class is present?

1. 95%
2. 80%
3. 75%
4. 25%
5. 20%

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN USE GRAPHS AND CHARTS.

38.

NAME	number of moons	approximate number of hours in a day	approximate length of a year (in earth years)
JUPITER	12	10	12
SATURN	9	10	29
MARS	2	24	2
URANUS	5	11	84
MERCURY	0	1400	1/4

This is a chart of information about 5 planets. Which of these planets has the longest year?

1. Jupiter
2. Saturn
3. Mars
4. Mercury
5. Uranus

39.

Look at the chart again. Which two planets have about the same length of day?

1. Jupiter and Saturn
2. Mars and Jupiter
3. Mars and Uranus
4. Mercury and Uranus
5. No two

GO ON TO PAGE 6

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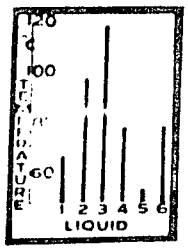
40.



BE SURE YOU ARE USING ANSWER SPACE 40

This is a graph of the boiling temperatures of 6 different liquids. Which liquid has the lowest boiling temperature?

1. Liquid 1
2. Liquid 3
3. Liquid 4
4. Liquid 5
5. Liquid 6

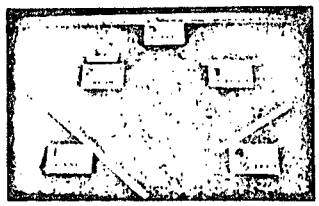
41.

Look at the graph again. Which two liquids have the same boiling temperature?

1. 6 and 4
2. 3 and 4
3. 1 and 5
4. 2 and 1
5. 3 and 5

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN MEASURE.

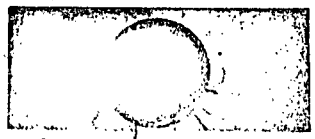
42.



This is a picture of 5 different rulers. Which one would be best for measuring how tall you are?

1. 1
2. 2
3. 3
4. 4
5. 5

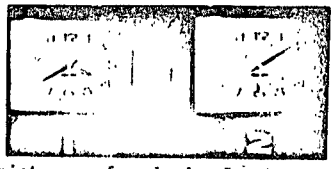
43.



This is a picture of a ball. Which of these would be best for measuring the distance around this ball?

1. Tape measure
2. Meter stick
3. Yard stick
4. 1-foot ruler
5. 6-inch ruler

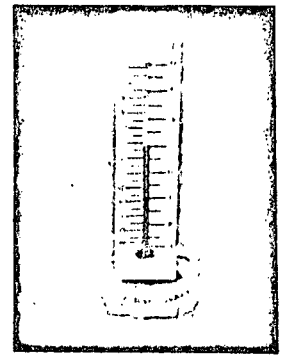
44.



These are two pictures of a clock. In picture 1, it is 3:40 in the afternoon. In picture 2, it is 6:10 that evening. How much later was picture 2 taken?

1. 2 hours and 30 minutes
2. 6 hours and 10 minutes
3. 3 hours and 40 minutes
4. 9 hours and 50 minutes
5. 9 hours and 30 minutes

45.



This is a picture of a thermometer in a glass of water. What is the temperature of the water?

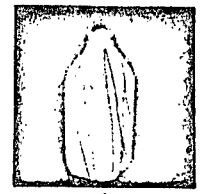
1. 50°F
2. 90°F
3. 20°C
4. 20°F
5. 0°C

46.

Which one of these units would be best to use in measuring the weight of a loaded freight car?

1. Pounds
2. Liters
3. Tons
4. Kilograms
5. Grams

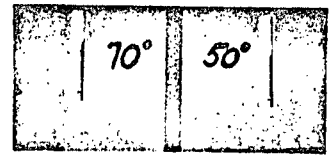
47.



This is a picture of a quart of milk. About how much does the milk weigh?

1. 10 milligrams
2. 1 gram
3. 5 ounces
4. 10 liters
5. 2 pounds

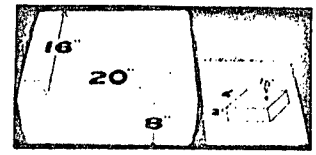
48.



These two pictures show a thermometer before and after it was cooled for 10 minutes. If its temperature went down at a steady rate, what was the rate?

1. 1 degree per hour
2. 1 degree per minute
3. 1 degree per second
4. 2 degrees per minute
5. 20 degrees per minute

49.



This is a picture of a box with its dimensions shown on it and a scale drawing of the box. One dimension is left out of the scale drawing. What should it be?

1. 1 inch
2. 2 inches
3. 3 inches
4. 4 inches
5. 5 inches

GO ON TO PAGE 7

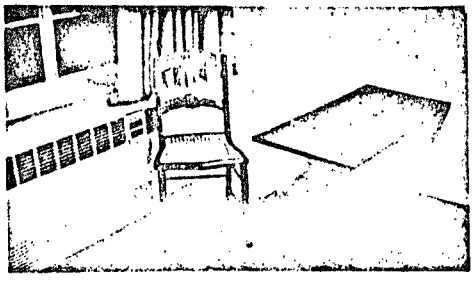
50.

BE SURE YOU ARE USING ANSWER SPACE 50

This is a picture of a little boy holding a ball. About how big is the ball?

1. 4 inches across
2. 5 centimeters across
3. 1/2 yard across
4. 1 meter across
5. 9 inches across

51.



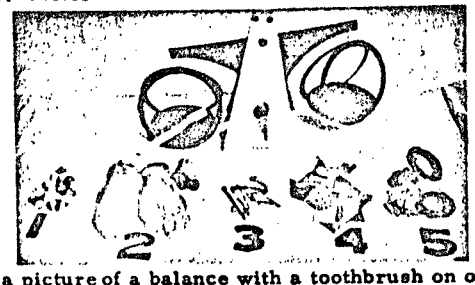
This is a picture of a room. Pretend that you are in this room and you want to measure its size, but you do not have a ruler. Which choice is NOT something you could use?

1. Your foot lengths
2. Floor tile lengths
3. Chair lengths
4. Window lengths
5. Table lengths

52.
Which one of these units is used in measuring area?

1. Inch
2. Cubic Centimeter
3. Yard
4. Square Kilometer
5. Meter

53.



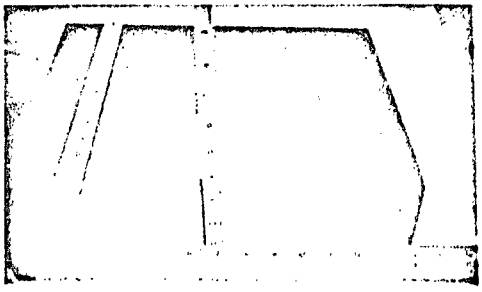
This is a picture of a balance with a toothbrush on one side. If you wanted to weigh the toothbrush, which group of objects would be best to use?

1. The marbles
2. The stones
3. The screws
4. The paper
5. The wires

54.
Which one of these units is NOT used in measuring weight?

1. Kilogram
2. Gram
3. Milligram
4. Kilometer
5. Pound

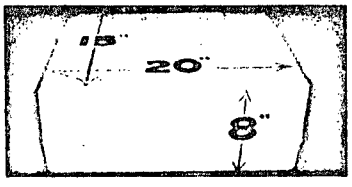
55.



This is a picture of a block. What are its dimensions?

1. 18 inches by 12 inches by 6 inches
2. 14 inches by 11 1/2 inches by 3 1/2 inches
3. 14 inches by 12 inches by 6 inches
4. 15 1/2 inches by 10 1/2 inches by 3 inches
5. 18 inches by 11 1/2 inches by 4 inches

56.



This is a picture of a box with its dimensions shown on it. What is the area of the top of the box?

1. 20 square inches
2. 300 square inches
3. 35 cubic inches
4. 160 square inches
5. 35 square inches

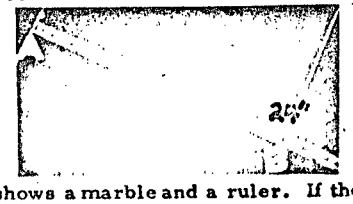
57.
Look at the picture of the box again. Which of these is NOT the volume of the box?

1. 15 inches times 20 inches times 8 inches
2. 300 square inches times 8 inches
3. 2,400 cubic inches
4. 160 square inches times 15 inches
5. 15 inches plus 20 inches plus 8 inches

58.
Which one of these is the number of seconds in an hour?

1. 2,400
2. 60
3. 600
4. 86,400
5. 3,600

59.



This picture shows a marble and a ruler. If the marble rolls from A to B in 2 seconds at a steady speed, how fast is it going?

1. 12 inches per 2 seconds
2. 24 inches per second
3. 2 feet per second
4. 1/2 foot per second
5. 1 foot per second

60.
Which one of these units would be best to use in measuring the distance from the earth to the moon?

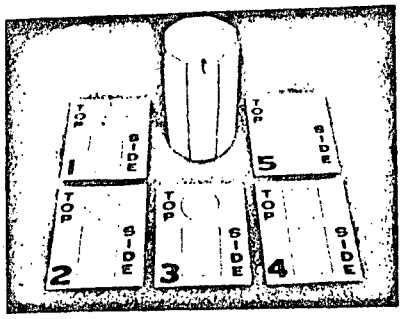
1. Yards
2. Feet
3. Inches
4. Miles
5. Light Years

BE SURE YOU ARE USING ANSWER SPACE 60

GO ON TO PAGE 8

DO NOT WRITE IN THE TEST BOOKLET

61.



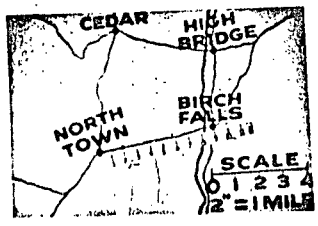
This is a picture of a box and 5 drawings. Which is the best drawing of the box?

1. 1
2. 2
3. 3
4. 4
5. 5

62.
Which one of these units is used in measuring length?

1. Centimeter
2. Gram
3. Square Yard
4. Acre
5. Quart

63.



This picture shows a part of a map. How far is it from North Town to Birch Falls?

1. 9 miles
2. 18 miles
3. 4 1/2 miles
4. 27 miles
5. 6 3/4 miles

64.
Look at the map again. If you were using the same scale to draw another map, how far apart would you place two towns which are actually 5 miles from each other?

1. 10 inches
2. 2/5 inches
3. 5 inches
4. 15 inches
5. 1 foot

65.
In which pair below are the measurements closest in size?

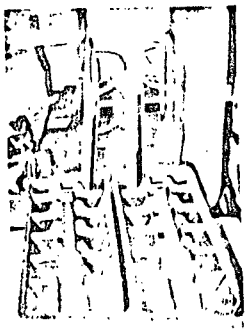
1. 2 1/2 kilograms and 1 pound
2. 2 1/2 centimeters and 1 inch
3. 5 kilometers and 1 mile
4. 5 liters and 1 quart
5. 10 yards and 1 meter

66.
In which pair below are the units closest in size?

1. Pound and kilogram
2. Yard and meter
3. Meter and mile
4. Gram and liter
5. Centimeter and foot

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN PLAN AND UNDERSTAND EXPERIMENTS.

67.



This is a picture of two ice cube trays. One is filled with very hot water and one with cold water. Many people say: "HOT WATER MAKES ICE CUBES QUICKER THAN COLD WATER." Which choice would be the best statement for helping you plan an experiment to test this?

1. The hotter the water you start with, the faster it will freeze into ice cubes.
2. Hot water freezes into ice cubes fast.
3. Hot water freezes at higher temperatures than cold water.
4. Hot water freezes into ice cubes faster because it turns on the refrigerator.
5. Hot water makes steam which keeps the refrigerator going.

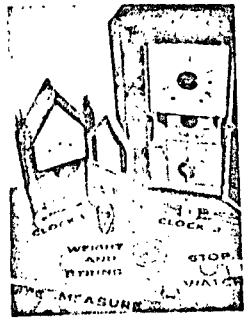
68.
If you wanted to test the statement you chose in the last question, which factor listed below is the only one you should allow to change during the experiment?

1. The temperature of the water you use.
2. The amount of water in each tray.
3. The position of the trays in the freezer.
4. The refrigerator in which you put the trays.
5. The kind of trays you use.

69.
Some things that can change during your experiment are listed below. Which one changes because of all the others?

1. The kind of trays you use.
2. The refrigerator in which you put the trays.
3. The time it takes for freezing.
4. The temperature of the water you use.
5. The amount of water in each tray.

70.



BE SURE YOU ARE USING ANSWER SPACE 70

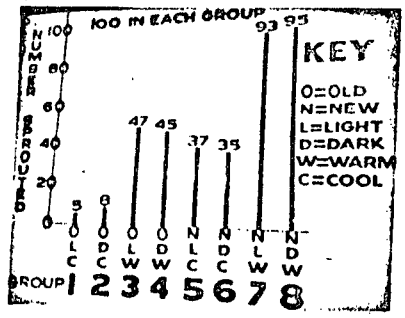
This is a picture of 5 objects. If you want to study the relationship between the length of a pendulum and how long it takes to complete one swing, which things would be best to use?

1. C and D only
2. A, B, and E only
3. A, C, and D only
4. A and B only
5. All of the things

GO ON TO PAGE 9

DO NOT WRITE IN THE TEST BOOKLET

71.



This is a graph of the results of an experiment.. 400 seeds that were 10 years old and 400 new seeds were planted in good soil and watered each day.
100 old seeds and 100 new seeds were put in a dark cool place.
100 old seeds and 100 new seeds were put in a light cool place.
100 old seeds and 100 new seeds were put in a dark warm place.
100 old seeds and 100 new seeds were put in a light warm place.

Five things which may affect the growth of seeds are: water, heat, soil, age, and light. Which of these were tested?

1. Heat, age, and light only
2. Soil, heat, and light only
3. Heat, soil, age, and light only
4. Water and soil only
5. Water and age only

72.
Look at the graph again. Here are some things you can see on the graph:
A. 365 seeds sprouted.
B. 400 seeds were 10 years old.
C. 400 seeds were new.
D. 400 seeds were kept cool.
E. 400 seeds were kept warm.
F. 400 seeds were kept in the light.
G. 400 seeds were kept in the dark.
Which one happened because of all the others?

1. A
2. B
3. D
4. F
5. G

73.
Look at the graph once more. Here are 5 statements about this experiment:
A. More new seeds sprout than old seeds.
B. Heat makes a difference in how many seeds sprout.
C. Light makes a difference in how many seeds sprout.
D. Water does not make a difference in how many seeds sprout.
E. Light does not make a difference in how many seeds sprout.
Which of these can you find from the graph?

1. A only
2. A, B, and D only
3. D and E only
4. C and D only
5. A, B, and E only

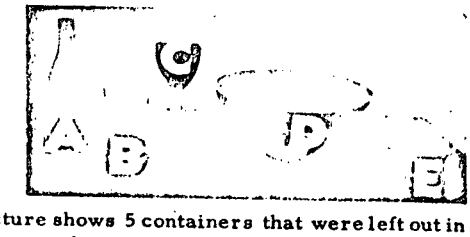
74.
Look at the graph again. Listed below are some other experiments you could do. Which one is NOT based on the experiment shown in the graph?

1. A study of seeds of several ages.
2. A study of the effect of different numbers of hours of light and dark on seeds.
3. A study of the heights of plants.
4. A study of the effect of different amounts of water on seeds.
5. A study of the effect of different temperatures on seeds.

75.
Look at the graph again. Why were 800 seeds used?

1. 800 makes 8 groups of exactly 100 each, and 100 is a round number.
2. Experiments require exactly 100 samples in each group.
3. 800 were all the seeds that were available.
4. The groups needed to be large enough so that what was found out was not wrong due to chance.
5. 800 happened to be the number taken out of the bag.

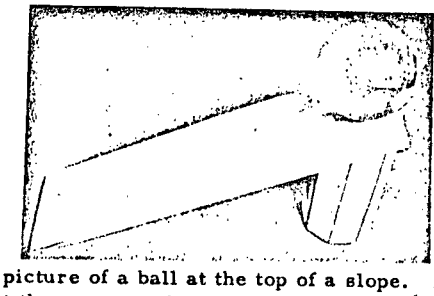
76.



This picture shows 5 containers that were left out in a storm. The rainwater has been colored so that you can see it better. Which is the best container to use to find out how many inches of rain fell?

1. A
2. B
3. C
4. D
5. E

77.



This is a picture of a ball at the top of a slope. If you want to find out the average time it takes for the ball to roll all the way down the slope, about how many times should you let it roll down and time it?

1. 1
2. 2
3. 15
4. 250
5. 1,000

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN FIGURE OUT AND PREDICT, WHEN YOU ARE GIVEN SOME FACTS. BE VERY CAREFUL TO THINK ABOUT YOUR ANSWERS. MAKE SURE THEY ARE BASED ON WHAT YOU SEE IN THE PICTURE OR CHART.

78. WIND DIRECTION

	SUN	MON	TUE	WED	THU	FRI	SAT
NOON	E	N E	E	E	S E	calm	E
MIDNIGHT	S W	W	W	calm	N W	W	W

This is a chart of wind direction at noon and midnight for one week. Which is the most general statement you can make based on this chart?

1. The direction of the day winds is 180° different from the direction of the night winds.
2. The direction of the wind is different at night than it is during the day at this place.
3. There is always a wind in this place.
4. Day winds come from the east and night winds come from the west.
5. It is warmer during the day than it is at night.

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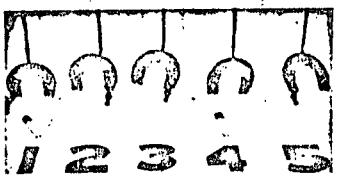
79.



This is a picture of 5 pins and 5 magnets. Which statement CANNOT be made just from looking at the picture?

1. Pins 2 and 5 have big heads.
2. Pins 2, 3, and 5 are sticking to their magnets.
3. Some pins are made from a metal which is not magnetic.
4. All the pins with big heads shown in this picture are sticking to their magnets.
5. Pins 1 and 4 are not sticking to their magnets.

80.

BE SURE YOU ARE USING ANSWER SPACE 80

Look at the picture again. What else must you do to prove that pins 2 and 5 are attracted to magnets?

1. See if pins 2 and 5 are magnetic.
2. See if magnets 2 and 5 are really magnets.
3. Take a magnet that you know is good and see if it attracts pins 2 and 5.
4. See if pins 2 and 5 attract each other.
5. See if magnets 2 and 5 attract each other.

81.

Look at the picture once more. Here are 6 possible facts:

A. Magnet 1 is a strong magnet.
B. Magnet 1 is NOT a magnet.
C. Pin 1 is glued to the table.
D. Pin 1 is loose on the table.
E. Pin 1 is made of steel.
F. Pin 1 is NOT made of steel.

Which facts must you know in order to be sure that pin 1 is NOT attracted to magnets?

1. B and C only
2. A and D only
3. F only
4. B and E only
5. D and F only

82

COUNTRY	AVERAGE RAINFALL INCHES PER YEAR
A	5.4
B	56.7
C	143.1
D	95.4
E	9.0
F	78.3
G	62.5

This is a chart of average yearly rainfall in 7 countries. Which countries are probably mostly desert?

1. A and B
2. B, D, F, and G
3. B and E
4. A and E
5. C and D

83.

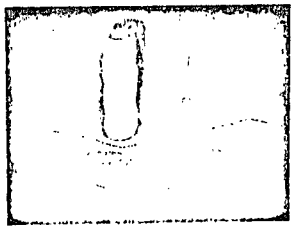
Look at the chart again. Here is a list of some other facts which you can get about these countries:

A. Fertility of the soil
B. Number of farmers
C. Value of farm crops
D. Size of the country
E. Average temperature

Which would help you decide what kinds of plants probably grow in each country?

1. B only
2. A, C, and E only
3. A and B only
4. C, D, and E only
5. A and E only

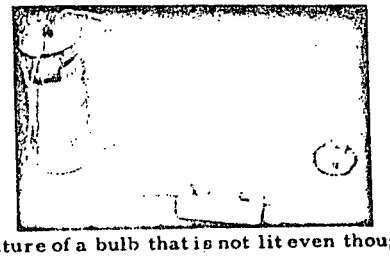
84.



This is a picture of some string. The manufacturer claims it will hold at least 100 pounds. What is the best way to check this?

1. Hang a weight of 75 pounds on the string, and keep adding 1-pound weights until it breaks.
2. Hang a 100-pound weight on the string, and see if it breaks.
3. Let two 100-pound boys pull on each end of a piece of the string, and see if it breaks.
4. Hang 101 pounds on the string and see if it breaks.
5. Double the string and hang 50 pounds from it, and see if it breaks.

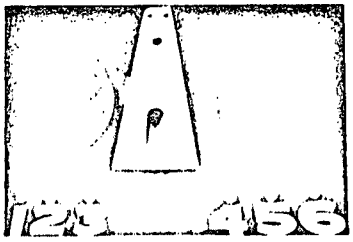
85.



This is a picture of a bulb that is not lit even though the switch is closed. Which of these statements is NOT a possible explanation?

1. The bulb is not screwed in tightly.
2. The battery is wired into the circuit backwards.
3. The bulb is burned out.
4. The battery is dead.
5. A wire is not making good contact.

86.



This is a picture of a balance and 6 marbles. Marbles 1, 2, and 3 all weigh the same. When marbles 1, 2, and 3 are put on one side and 4, 5, and 6 are put on the other side, they balance. Which other facts do you need to know in order to say that all the marbles weigh the same?

1. Marble 5 weighs the same as marble 2.
2. Marble 5 weighs the same as marble 2 and marble 1.
3. Marble 3 weighs the same as marble 6.
4. Marble 4 weighs the same as marble 5 and marble 6.
5. Marble 3 weighs the same as marble 5.

87.

This is a picture of a barometer. From reading it, which of the following statements about the weather can you make?

1. The barometric pressure is rising.
2. You do not have enough information to tell what will happen.
3. The weather is changing.
4. It will rain in two days.
5. The barometric pressure is falling.

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88.

A METAL BAR

TEMPERATURE	LENGTH
10°C.	100 cm
30°C.	101 cm
50°C.	102 cm
90°C.	104 cm

This is a chart of the change in length of a metal bar as it is heated. Use the chart to figure out what its length is at 40°C.

1. 101 centimeters
2. 101.5 centimeters
3. 102 centimeters
4. 102.5 centimeters
5. 103 centimeters

89.

Use the chart to figure out what the length of the bar probably is at 100°C.

1. 103.5 centimeters
2. 104 centimeters
3. 104.5 centimeters
4. 105 centimeters
5. 105.5 centimeters

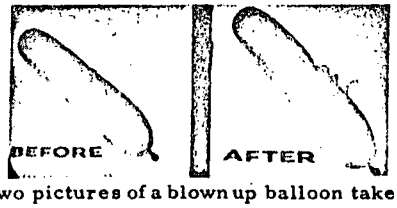
90.

BE SURE YOU ARE USING ANSWER SPACE 90

What is the best way to check the answers you gave to the last two questions?

1. Measure the bar at 100°C, and then graph all the numbers to check your answers.
2. Put your answers on the chart and see if they look correct.
3. Measure the bar at 120°C, and then make a graph of all the numbers to check your answers.
4. Measure the bar at least 5 times at other temperatures, and compare what you find with your answers.
5. Measure the bar at 40°C and at 100°C and compare what you find with your answers.

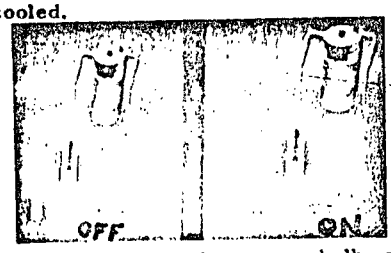
91.



These are two pictures of a blown up balloon taken before and after heating. When you heat the balloon, it gets bigger. When you cool the balloon, it gets smaller. Why?

1. Gasses get bigger when heated and smaller when cooled.
2. All things get smaller when heated and bigger when cooled.
3. Liquids get bigger when heated and smaller when cooled.
4. Plastics get bigger when heated and smaller when cooled.
5. Solids get bigger when heated and smaller when cooled.

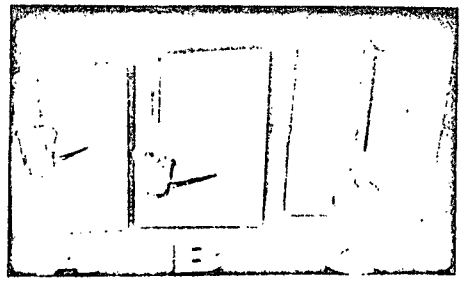
92.



These are two pictures of a battery, a bulb, a switch, and some wires. Which is the only thing you can be sure is different between picture 1 and picture 2?

1. The bulb was replaced.
2. The wires were tightened.
3. The bulb was screwed in.
4. The battery was electrically recharged.
5. Electricity is flowing through the bulb.

93.



This is a picture of three rubber-band scales which are all alike. Scale A has 3 marbles on it. Scale B has 5 marbles on it. Scale C has 7 marbles on it. If you put another marble on scale B, the pointer will probably point to about "6." Why?

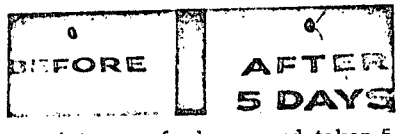
1. "6" is halfway between "5" and "7."
2. The amount a rubber band stretches depends on how much weight is pulling it.
3. Rubber bands stretch.
4. Then there will be one more marble on scale B.
5. The numbers on the scales were put on after trying out different numbers of marbles.

94.

In order to prove that "NOT ALL THINGS GET BIGGER AS YOU HEAT THEM," which of the following would you need to do?

1. Find one thing that does not get bigger when it is heated.
2. Find all the things that do not get bigger when they are heated.
3. Find one thing that gets bigger when it is heated.
4. Find all the things that get bigger when they are heated.
5. Find all the things that do not change size when they are heated.

95.



These are two pictures of a bean seed taken 5 days apart. What is most likely to have caused the change in the seed?

1. Light
2. Fertilizer
3. Heat
4. Water
5. Plant food

96.

In order to make this statement: "THE COLDER A CITY IS, THE MORE SNOW IT HAS," which of the following do you need to know about some cities?

1. The average temperature of each city and the number of snowplows each has.
2. The number of days school was closed in each city because of snow.
3. The average temperature and precipitation of each city.
4. The average temperature and average snowfall of each city.
5. The average number of times it snows in each city.

MAKE SURE THAT YOUR ANSWERS ARE BLACK AND COMPLETELY FILL THE SPACES. MAKE SURE THAT YOU HAVE COMPLETELY ERASED ANY MISTAKES OR STRAY MARKS ON YOUR ANSWER SHEET. YOU MAY GO BACK AND WORK ON ANY SECTION OF THE TEST UNTIL TIME IS CALLED BY THE TEACHER.

A P P E N D I X C

SUMMARY OF CELL MEANS FOR ANALYSIS OF COVARIANCE

Achievement Test

			Teacher-Paced		Self-Paced	
	Teacher		1	2	1	2
Sex	Male	$\bar{x}$	28.20	32.00	32.50	40.17
		n	10	11	8	6
	Female	$\bar{x}$	25.43	33.63	33.33	31.59
		n	7	8	6	17

Retention Test

			Teacher-Paced		Self-Paced	
	Teacher		1	2	1	2
Sex	Male	$\bar{x}$	27.90	30.55	29.25	37.00
		n	10	11	8	6
	Female	$\bar{x}$	26.57	29.75	31.67	30.47
		n	7	8	6	17

Science Processes

			Teacher-Paced		Self-Paced	
	Teacher		1	2	1	2
Sex	Male	$\bar{x}$	20.30	20.09	27.50	28.50
		n	10	11	8	6
	Female	$\bar{x}$	24.00	24.50	23.83	26.94
		n	7	8	6	17

Attitude to Experimenting

			Teacher-Paced		Self-Paced	
	Teacher		1	2	1	2
Sex	Male	$\bar{x}$	49.80	49.18	57.33	37.33
		n	10	11	9	6
	Female	$\bar{x}$	33.29	49.00	44.50	44.65
		n	7	8	6	17

Attitude to Independent Investigation

			Teacher-Paced		Self-Paced	
	Teacher		1	2	1	2
	Male	$\bar{x}$	51.20	63.91	62.22	45.83
	Female	n	10	11	9	6
Sex	Male	$\bar{x}$	41.00	61.50	58.00	53.82
	Female	n	7	8	6	17

A P P E N D I X D

FRANK HURT SECONDARY SCHOOL

OPTICS
STUDENT OUTLINE AND EVALUATION

NAME_____

Sequence	Practice	Topic	Date Completed
1	Lecture Chapters 25 and 26	Introduction Introduction and Other Sources of Light p. 118 Ques. 1 - 3 p. 122	
2	Lab 4 - 1	Light Sources p. 164 Ques. 1 - 6 p. 166 - 167	
3	Chapters 27	Witches' Light Ques. 1 - 4 p. 126	
	28	Cold Light Ques. 1 - 4 p. 129	
4	Lab 4 - 2	Light passes through Ques. 1 - 3 p. 166 - 167	
5	Chapter 29		
6	Test	Collect Exercise Books	
7	Lab 4 - 3	The path taken by light Ques. 1 - 8 p. 171	
8	Chapter 30	The Solar Eclipse p. 132 Ques. 1 - 7 p. 137	
9	Lab 4 - 4	Shadows Ques. 1 - 6 p. 174 - 176	
10	Test	Collect Exercise Books	
11	Lab 4 - 5	Formation of Images Ques. 1 - 2 p. 179	

Sequence	Practice	Topic	Date Completed
12	Chapter 37	Windows of Sand Ques. 1 - 4 p. 168	
13	Appendix 7	Read p. 241 - 243 in the lab. test	
14	Lab 4 - 6	Refraction by a Transparent Solid Ques. 1 - 5 p. 185	
15	Chapter 38	The Glassmakers Ques. 1 - 4 p. 170	
16	Lab 4 - 7	Making Use of Refraction Lenses	
17	Filmstrip	The Story of Lenses Ques. 1 - 5 p. 191	
18	Chapter 39	Making a Lens Ques. 1 - 2 p. 172	
19	Test	Collect Exercise Books	
20	Lab 4 - 11	Studying Reflection Ques. 1 - 10 p. 212 - 213	
21	Chapter 33	Mirrors in the Beginning Ques. 1 - 4 p. 148	
22	Lab 4 - 12	Images in a Plane Mirror Ques. 1 - 7 p. 216 - 217	
23	Chapters 31	Mirrors Ques. 1 - 3 p. 140	
	32	Mirrors in Use Ques. 1 - 5 p. 145	
24	Lab 4 - 13	Cylindrical Curved Mirrors Ques. 1 - 3 p. 220	
25	Test	Collect Exercise Books	
26	Lab 4 - 8	Using a Spherical Convex Lens to Produce an Image Ques. 1 - 8 p. 196 - 197	

Sequence	Practice	Topic	Date Completed
27		Enrichment Lens Makers Formula and Worksheet	
28	Chapter 36	Ques. 1 - 4 p. 163	
29	Lab 4 - 9	Defects in Vision and How to Correct Them	
30	Chapter 11	Ques. 1 - 11 p. 56	
31	Lab 4 - 10	Prisms and Colour Ques. 1 - 3 p. 207	
32	Filmstrip		
33	Test	Collect Exercise Books	

FRANK HURT SECONDARY SCHOOL

OPTICS

This unit is concerned with the study of light and its behaviour. You will perform experiments to determine the nature of light:

(a) How it travels.

(b) How it is reflected.

(c) How it is refracted.

OBJECTIVES OF OPTICS

A. NATURE OF LIGHT

1. To determine different ways in which light is produced by man.

2. To classify light sources.

3. The conditions necessary for seeing.

4. To classify materials according to how light passes through them.

B. PATH OF LIGHT

1. To determine the path of light.

2. To determine how shadows are formed.

3. To determine the types of shadows that can be formed by different light sources.

C. FORMATION OF IMAGES

1. To find how you can produce a real image.

2. To find out how the position of the object in front of the pinhole affects the size and condition of the image that is produced.

3. To find how moving the screen changes the image on the screen.

D. REFRACTION OF LIGHT

1. To be able to measure angles with a protractor.
2. To state the law of refraction.
3. To find where a light ray is bent when it passes from one medium to another.
4. To determine how different material affects the angle of diffraction.
5. Observe how the shape of lenses is used to change the path of light.

E. REFLECTION OF LIGHT

1. To observe the nature of images in a plane mirror.
2. To state the law of reflection.
3. To observe reflection from a rough surface.
4. To determine why objects are coloured.
5. To determine where images are located in a plane mirror.
6. The uses of mirrors.

F. CURVED MIRRORS

1. To observe how convex and concave mirrors reflect light rays.
2. To determine the nature of the image formed by a spherical convex lens.
3. To determine how to change the size and nature of the image formed by a spherical convex lens.

G. DEFECTS IN VISION

1. To learn the defects in vision.
2. To determine how to correct the defects in vision.
3. To learn the parts of the human eye.

H. PRISMS AND COLOUR

1. To learn how to use a prism to show reflection and refraction of light.

2. To observe how a prism can separate the colour in white light.

BEHAVIORAL OBJECTIVES FOR THE UNIT OPTICS

Sequence 1 — The student will learn the difference between incandescent and luminescent sources of light.

Sequence 2 — The student will learn how to classify light sources as being point sources, broad sources, luminous and non-luminous. The student is also to learn how a ray box operates.

Sequence 3 — The student will define the terms bioluminescence, chemiluminescent, phosphors, and fluoroscope. The student is also to learn the difference between fluorescent and phosphorescent phosphors.

Sequence 4 — By doing Lab 4 - 2 the student will learn the meanings of opaque, transparent and translucent. The student will learn to classify objects according to how they let light pass through themselves.

Sequence 5 — The student will learn the meaning of the word electroluminescence and three advantages of electroluminescent light by reading Chapter 29.

Sequence 6 — The student will review objective A and the definitions from the chapters and labs and demonstrate his understanding by writing a test.

Sequence 7 — The student will observe how to see light by doing procedure Part A of lab 4 - 3 and the path of light by doing procedure B of the same lab.

Sequence 8 — The student will learn how eclipses come about and how they give further proof of the path of light.

Sequence 9 — The student will learn how shadows are formed and the meaning of the words umbra and penumbra. The student will also observe the different shadows formed by a single point source and by two point sources.

Sequence 10 — The student will demonstrate his understanding of the path of light, objectives A and B, by writing a test.

Sequence 11 The student will do lab 4 - 5 and from it

(a) define the terms image, erect, inverted, real image.

(b) observe how moving the object changes the size and nature of the image.

(c) observe how moving the screen changes the size and nature of the image.

(d) by answering the questions 1 - 4 on pages 180 - 181 the student will learn why the image has formed.

Sequence 12 The student will define the terms lehr, annealed and will learn the materials that are used to make glass and also how different types of glass are made.

Sequence 13 The student will learn the meanings of exterior angle, interior angle, vertex, right angle, straight angle and how to measure angles with a protractor by reading appendix 7 and performing the exercises on p. 242 on the lab text.

Sequence 14 The student will define the terms normal, incident ray, refracted ray, refraction, angle of incidence, and angle of refraction. He will also state the law of refraction.

Sequence 15 By reading chapter 38 the student will learn the difference between plate glass, sheet glass and float glass as well as how these three types of glass are made and the advantages of each type of glass.

Sequence 16 The student will learn the difference between convex and concave surfaces and how cylindrical, concave and convex surfaces differ in their effect on parallel beams of light. The student will also define the terms lens axis, principal axis, principal focus, focal length, and virtual.

Sequence 17 The student will review lenses by viewing the filmstrips "The Story of Lenses".

Sequence 18 The student will learn the procedure for making lenses by reading chapter 39.

Sequence 19 The student will demonstrate his knowledge and understanding of objective D by writing a test.

Sequence 20 The student will define the terms real and virtual images and will state the law of reflection. He will also learn why coloured objects are the colour they are.

Sequence 21 The student will learn different types of mirrors man makes and their uses.

Sequence 22 The student will learn where the image in a plane mirror is located.

Sequence 23 The student will define the terms laterally inverted, sextant, corner and reflector and some further uses of mirrors.

Sequence 24 The student will learn how concave and convex mirrors form images and what kinds of images they will form. The terms focal length, principal axis, principal focus, converging and diverging will be defined and applied to mirrors.

Sequence 25 The student will demonstrate his understanding of objectives E and F by writing a test.

Sequence 26 The student will learn how to form an image with a spherical convex lens. He will also learn how changing the object distance affects the image distance and the nature of the image.

Sequence 27 The student will learn how to predict where the image will be by using the lens maker's formula.

Sequence 28 The student will learn how lenses and mirrors are used to make large telescopes and the three main focal points of telescopes.

Sequence 29 The student will learn the parts of the eye: retina, cornea, ciliary muscle and lens, and he will learn how eye defects can be corrected. He will define the terms myopia, hypermetropia and astigmatism.

Sequence 30 The student will learn about different eye structures in animals by reading chapter 11 and doing the questions to the chapter.

Sequence 31 The student will learn how prisms can be used to reflect and refract light and to produce a spectrum.

Sequence 32 By viewing the filmstrip "Geometrical Optics" the student will review the nature of lenses.

Sequence 33 The student will demonstrate his knowledge and understanding of objectives G and H by writing a test.

NOTE: The student will have to re-write any test that is not satisfactorily done.