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Title: The Effects of Higher Cognitive Level Question Wait-Time Ranges by Biology Student Teachers on Student Achievement and Perception of Teacher Effectiveness

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Thomas P. Evans, Ph. D.

The purposes of the study were to determine the relationship which existed between higher cognitive level question wait-time range and student achievement, and whether students perceived biology student teachers who used a 1-4 second wait-time range as being either more or less effective than biology student teachers who used a 4-7 second wait-time range. Seventeen student teachers taught a sixty minute instructional unit on the interrelationships of science, society and technology to each of two grade eleven biology classes by using a 1-4 second wait-time range in one class (treatment 1), and a 4-7 second wait-time range in the other class (treatment 2) when asking higher cognitive level questions.

Eight of the seventeen student teachers were successful in achieving the criterion wait-time range for

at least 70 percent of the higher cognitive level questions asked during each treatment. Four of the eight student teachers used the 1-4 second wait-time range first, and four used the 4-7 second wait-time range first.

The three data collecting instruments included an achievement test on the cognitive objectives of the grade X biology program which served as a covariate measure, an achievement test on the cognitive objectives of the treatment lesson, and a questionnaire aimed at determining student perceptions of student teacher effectiveness in teaching and in asking questions.

Fifteen student response sheets having responses to all instruments were randomly selected from each treatment group class. Analysis of covariance, with confirmation by analysis of variance, indicated that treatment group 2 students achieved significantly higher than treatment group 1 students($P < 0.001$). Hotelling's T^2 analyses indicated that the treatment groups perceived their student teachers differently ($P = .037$).

Observations made during the investigation suggested that neither mean wait-times nor wait-time ranges are adequate descriptors of teacher question wait-time when used separately, and that both measures should be used in describing research in this area.

The Effects of Higher Cognitive Level Question Wait-Time Ranges by Biology Student Teachers on Student Achievement and Perception of Teacher Effectiveness

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CHAPTER I

INTRODUCTION

Background of the Study

The functions of questions, their use as a teaching strategy and their effects on student behaviors and learning have been the focus of innumerable writings and studies for more than a half century (Stevens, 1912; Lancelot, 1929; Dewey, 1939; Houston, 1938; Gall, 1970; Hunkins, 1970; Balzer, Evans and Blosser, 1973; Rowe, 1977; Blosser, 1973; McGlathery, 1978 and Winne, 1979). Educators agree that questioning remains as one of the most common teaching methods employed (Orlich *et al* 1980).

Research efforts on questioning have resulted in the development of a number of classification systems which classify teachers' and students' questions as to type and cognitive level (Crump, 1970; Gall, 1970; McGlathery, 1978). The studies using such systems have mainly focused on the elementary grade levels. Associated observations have consistently revealed that teachers tend to ask a great majority of low cognitive level questions at astounding rates (Stevens, 1912; Bellack, 1966; Gall, 1970; King, 1975).

Training programs aimed at the development of question asking strategies have been developed, mainly to increase the number of higher cognitive level questions and decrease the number of lower cognitive level questions (Galloway and Mickelson, 1973; Clegg, 1967; Arnold, Atwood and Rogers, 1974; and Winne, 1979). Studies associated with such training sessions found that trained groups have indeed, asked more higher cognitive level questions. However, Rowe (1977), points out that the total number of questions also tends to increase. Arnold, Atwood and Rogers (1974), report that whether teachers ask simple or complex questions, their wait-time does not change. It would seem that teacher training programs aimed at developing better question asking strategies should also be concerned with developing strategies which would allow students time to think, particularly when higher cognitive level questions are asked.

Frequently, research on the effects of questioning strategies uses student achievement as the dependent variable. Winne (1979), reviews experimental and quasi-experimental studies and summarizes the evidence of the effects of teacher higher cognitive level versus fact questions on student achievement. He reports that such research has not conclusively related effectiveness of teacher use of higher cognitive level questions to enhanced student achievement. Rowe (1974) and Riley (1980a), suggest that this may be due, in part, to their omission of wait-time as an interacting variable. Studies where teachers have used increased wait-time have found that when teachers increase their wait-time, various improvements in students' and teachers' classroom questioning and responding patterns result (Rowe, 1974; McGlathery, 1978).

Need for the Study

Few studies have attempted to determine whether teacher question wait-time effects student cognitive achievement. Anderson (1978), studied the effect of wait-time on high school physics students' response length, classroom attitudes, science attitudes and achievement. He concluded that pupils, when given a longer wait-time, made longer responses, were more apathetic about the class and found the material less difficult than they anticipated. No achievement differences were reported in relation to wait-time. Tobin (1980) and Riley (1980a), both reported research with elementary level pupils which indicated that the use of an extended teacher question wait-time leads to higher science achievement. The need for this study arises directly from this limited amount of research which has presented somewhat contradictory findings.

Researchers who have studied the effects of extended teacher question wait-time on student classroom behaviors have indicated that the involved teachers had experienced some difficulties in achieving the specified extended question wait-times (Rowe, 1977; Riley, 1980b, Tobin, 1980). A further justification for this study is that it will provide information pertaining to these expressed difficulties, as follows:

1. Information of the experiences of student teachers in attempting to achieve specified wait-time ranges will be summarized;
2. Questioning strategies used by student teachers in their attempts to achieve the specified question wait-time ranges will be presented and the attempts to develop and outline a strategy which may assist teachers in achieving different wait-time ranges will be reported; and,
3. Student teacher achievement of specified question wait-time ranges will be determined.

Such information will be useful to student teachers, pre-service teacher instructors and researchers.

The study is also significant in view of the increasing concern for the development of scientific literacy among students through the discussions of the interrelationships of science, society and technology (Page, 1979). A product of this study will be such an instructional unit prepared by the involved student teachers which will be available for future use. In the preparation and presentation of the unit, student teachers, cooperating teachers and biology students will have opportunity to further develop their scientific literacy.

Simpson (1978) reports that researchers agree that the interaction between students and teacher represents one of the most significant variables in the education process and that the classroom is a complex psycho-social environment. This study is further justified in that it will provide some information as to how high school students perceive biology student teachers and their teaching of biology when they use different wait-times for higher cognitive level questions.

Statement of Problems

The problems studied in this research are associated with biology student teachers' use of two different higher cognitive level question wait-time ranges. More specifically, the problems are as follows:

1. To examine the possible relationship between biology student teacher higher cognitive level question wait-time range and student achievement; and,
2. To determine whether grade XI biology students perceive student teachers who use a longer higher cognitive level question wait-time range as being more or less effective than student teachers who use a shorter higher cognitive level question

wait-time range.

The Null Hypotheses

The hypotheses to be tested are as follows:

H_1: There is no significant difference ($\alpha = 0.05$) between the mean achievement level of grade XI biology students taught by biology student teachers using a 1-4 second higher cognitive level question wait-time range and the mean achievement level of students taught by the same student teachers using a 4-7 second higher cognitive level question wait-time range.

H_2: There is no significant difference ($\alpha = 0.05$) in the students' perception of the effectiveness of biology student teachers who use a 1-4 second high cognitive level question wait-time range when compared to students' perceptions of the effectiveness of biology student teachers who use a 4-7 second higher cognitive level question wait-time range.

Assumptions

For this study, it is assumed that:

1. Achievement of specified learning objectives can be reliably measured by performance on an achievement test;
2. The grade X items of the Alberta Biology

Achievement Test - Form B, are valid and reliable;

3. The use of student perceptions is a valid and reliable means of measuring teacher effectiveness.

Definitions of Terms

Achievement: Refers to the mastery of particular knowledge in specific areas. Achievement will be determined by student responses to objective type test items which had been developed in association to particular cognitive objectives in a unit of study.

Biology student teachers: These are preservice teachers who are in their last year of a four year biology teacher education program at the University of Alberta in Edmonton.

Students: Are those grade XI biology students participating in the study from Edmonton area composite senior high schools studying the biology 20 Alberta Education curriculum program with teacher education cooperating teachers.

Wait-Time: This is the time interval which begins when the teacher stops speaking during the question asking strategy and terminates when the teacher calls upon a student for a response, a student begins a response, or the teacher speaks again.

Wait-Time 1: Wait-time 1 is a higher cognitive level question wait-time within a 1.0-4.0 second range.

Wait-Time 2: Wait-time 2 is a higher cognitive level question wait-time within a 4.0-7.0 second range.

Low cognitive level questions: Those questions that require only recall and memorization as defined by cognitive memory questions in Blosser's Question Category System for Science (Blosser, 1973).

Higher cognitive level questions: Those questions which require either convergent thinking, divergent thinking or evaluative thinking according to Blosser's Question Category System for Science (Blosser, 1973).

Treatment 1: When the student teacher uses a wait-time 1 pattern.

Treatment 2: When the student teacher uses a wait-time 2 pattern.

Treatment 1 students: Are those students taught by a student teacher using a wait-time 1 pattern.

Treatment 2 students: Are those students taught by a student teacher using a wait-time 2 pattern.

Group 1 student teachers: Are those student teachers who teach the treatment instructional unit to one class using wait-time 1 pattern prior to teaching a second class the same instructional unit using wait-time 2 pattern.

Group 2 student teachers: Are those student teachers who teach the treatment instructional unit to one class using wait-time 2 pattern prior to teaching a second class the same instructional unit using wait-time 1 pattern.

<u>Limitations of the Study</u>

1. The accuracy of wait-time measurements is limited by the technical accuracy of the strip chart recorder and the abilities and skills of the technician.
2. The time for practicing questioning strategies and question wait-time ranges is determined by the cooperating teachers' programs.
3. The scheduling of the instructional periods and administration of the dependent variable measures is determined to some extent by the cooperating teachers programs.
4. The study is limited by the extent of the effect that the presence of a tape recorder has on the behaviors of the students and student teachers.
5. Each class in the treatment groups will have been taught by a cooperating teacher who practiced certain questioning strategies. There are no attempts made to control or direct those strategies and this study is limited by the effect that those strategies have on the behaviors of the students during the study.

Delimitations of the Study

1. This study considers only the wait-time that occurs between the teacher's question and the student's response. The wait-time that occurs between a student's response and the next comment is not considered.
2. Teacher questions are categorized as to low cognitive level and high cognitive level questions only (as defined).
3. The categorizing of questions is done in accordance with Blosser's Question Category System for Science (1973) on the basis of the intent of the question. It did not attempt to determine the actual thought processes that students performed in their efforts to formulate a response to any of the questions.
4. Classroom questions asked by the student teachers are recorded by audio-tape only. No attempts are made to study non-verbal classroom interactions.

Design of the Study

A. Populations

1. Student Teachers

The study will involve all the biology student teachers enrolled in the Phase III biology teacher education program at the University of

Alberta during the winter session, 1981. All student teachers will have satisfactorily completed five weeks of in-school experiences as follows:

(i) The equivalent of one week classroom observation activites made up of 10 half-day per week sessions over a 14 week period during their second year in the program; and,

(ii) Four weeks of in-school experiences which included some teaching of individual lessons with pre-lesson and post-lesson conferences, usually during the third year of a four year program.

2. Students

Each student teacher will use two junior high school classes during the first round of student teaching to practice the different higher cognitive level question wait-time ranges and to attempt different question asking strategies.

In the research, each student teacher will use two biology 20 classes belonging to his/her senior high school cooperating teacher during the second round of student teaching. One class will be taught the treatment lesson with a 1-4 second higher cognitive level question wait-time range and one class will be taught the same lesson with a 4-7 second higher cognitive level question wait-time range.

B. Instrumentation

1. Cassette tapes and recorders will be used to record verbal questioning during the teaching of the treatment lessons.
2. The higher cognitive level question wait-time will be measured with the use of a strip chart recorder for each student teacher.
3. A 40 item pretest made up of grade X items from the Alberta Biology Achievement Test - Form B shall be validated and administered to the treatment groups. The administration of the test will occur at the beginning of the semester in which the study will take place.
4. An objective test shall be used as a post-test measure of the students' achievement of the instructional objectives of the unit taught by the student teachers during the treatment lessons.
5. A rating scale shall be designed and used to assess the students' perceptions of their student teacher's effectiveness in teaching and in using questions during the instruction of the treatment

lessons.

C. Pilot Study

A pilot study will be done during the fall term, 1980. All prepared protocol materials will be used by a selected group of biology teacher education student teachers in the phase III program. The pilot study student teachers' abilities to achieve particular higher cognitive level question wait-time ranges during classroom instruction will be determined from the audiotape and strip chart recordings. The percent success in achieving particular higher cognitive level question wait-time ranges will be calculated for the higher cognitive level questions for each student teacher and the criterion level for percent success will be set for the study.

Validity of the instruments will be determined by a panel of judges made up of science teacher educators and graduate students from the Department of Secondary Education at the University of Alberta. This will be done prior to their use in the pilot study so that further revisions and refinements can be done as necessary.

Reliability of the achievement test and rating scale will be determined during the pilot study and revisions made as necessary.

D. Procedures

The study will take place over the 14 week winter term, 1981, as follows:

1. Of the schools in the Edmonton area accepting biology student teachers, a sufficient number will be randomly selected to accomodate all of the biology student teachers who are student teaching during that term.
2. During the first two weeks of the school semester, the treatment groups will be pre-tested with an objective test made up of the grade X standardized achievement test items from the Alberta Biology Achievement Test - Form B.
3. During the first three weeks of the phase III program when the student teachers are enrolled in Ed. C.I. 370 (Education Curriculum and Instruction 370), they will study and use Blosser's Question Category System for Science (Blosser, 1973), develop and practice question asking strategies, and practice higher cognitive level question wait-time ranges of 1-4 and 4-7 seconds.
4. During the first round of student teaching (weeks 4-7 of the term), the student teachers

will choose two junior high school classes and practice each wait-time range. Their efforts will be audiotaped and self analyzed for achievement of the wait-time ranges.

5. During weeks 8-10 of the term, the student teachers will return to the university and be enrolled in Ed. C.I. 371 (Education and Curriculum and Instruction 371), in which they will be involved in preparing for the presentation of the treatment lessons, as follows:

   (i) They will further analyze their junior high school teaching tapes for wait-time patterns and practice using the two different wait-time ranges during peer teaching activities; and,

   (ii) They will receive protocol materials for teaching selected aspects of the interrelationships among science, society and technology. They will also receive a list of specified instructional objectives for the protocol materials. The student teachers will then prepare lesson plans for two thirty-minute lessons which incorporate the protocol materials and include listings of low and higher cognitive level questions in approximately equal proportion to assist students in achieving the specified objectives.

6. During the second round of student teaching (weeks 11-14 of the term), the student teachers will teach the instructional unit to two different classes of grade XI (biology 20) students. Through random selection, half of the student teachers will teach the unit using a 1-4 second higher cognitive level question wait-time range with the first class and a 4-7 second higher cognitive level question wait-time range with the second class. The other student teachers will use the reversed sequence with their treatment groups. The lessons will be audiotaped, the questions transcribed, and the wait-time for each higher cognitive level question will be measured for each student teacher.
7. The rating scales will be administered and the results used to determine differences in student perceptions of student teacher effectiveness between treatment groups.
8. The achievement test on the objectives of the science, society and technology instructional unit will be administered and the results used

to determine differences in student achievement between treatment groups.

E. Design Matrix

The design matrix presented in Figure 1 applies to both the achievement test and student appraisal of student teacher effectiveness.

Students	Pretest	Treatment	Achievement Test and Appraisal Scales
Treatment I (1-4 second wait-time range	40 item biology achievement test	Taught by Group 1 student teachers	N = approx. 120*
		Taught by Group 2 student teachers	N = approx. 120*
Treatment 2 (4-7 second wait-time range)		Taught by Group 1 student teachers	N = approx. 120*
		Taught by Group 2 student teachers	N = approx. 120*

* The estimate of N = 120 is a maximum based on the random selection of 15 student answer sheets from each of 8 classes.

Figure 1 : Design Matrix

Methods of Analysis

Hypothesis H_1 will be tested for by the use of the analysis of covariance and Hypothesis H_2 will be tested for by the use of the Hotelling's T^2.

Organization of the Remainder of This Dissertation

The remainder of this dissertation is presented in four chapters. Chapter II presents a summary of published literature and research relevant to this study. Chapter III details the pilot study procedures and findings integrated with the experimental design and procedures used. Chapter IV has the results and analyses of data and chapter V presents the summary and conclusions of the study and recommendations for further research and practice in this area.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

Introduction

This chapter presents a summary of published literature and research that is relevant to this study. It begins with a review of literature on the use of questions as a teaching strategy. The next section deals with the various systems for classifying questions with particular reference to Blosser's Question Category System for Science (1973) and the findings resulting from research involving the classification of teacher questions. The effects of teacher questions on pupil performance is considered next, followed by a discussion of the questioning cycle with particular reference to teacher question wait-times used in that cycle. Finally, the levels of success that result from the training of teachers in the use of particular questioning patterns is considered and the main aspects of this literature on questioning as they relate to this study are presented in a brief summary.

Questioning as a Teaching Strategy

Since the time of Socrates, questioning has been recognized as one of the major strategies of teachers.

Ruddell (1974, p. 336) identifies the question as "a basic and commonly accepted tool used to stimulate thinking and enhance the cognitive process and comprehension ability." In Taba's view, questions and the act of asking them play a crucial role in focusing, expanding and directing thinking in a teaching strategy (Taba, 1965, p. 538).

Considering the esteemed value of questioning in teaching, it is not surprising that questioning in the classroom continues to be the focus of considerable research. Over half a century ago, it was disclosed by Stevens (1912) that questioning comprised a large portion of the teacher's daily verbal output. In observation of a number of high school teachers, she found that a mean of 395 questions were asked daily, and estimated that four-fifths of instructional time were occupied with question-and-answer recitation. Some fifty years later, Flanders (1963) supported this statistic. He reported that the asking of questions and the giving of information accounts for 70 - 90 percent of teacher talk. More recent reviews verify the ongoing practice of extensive and high frequency question asking by teachers. Gall (1970) cites several studies in elementary classrooms in which large numbers of questions were used - ranging from 64 - 180 in one class period to an average of 348 questions during the school day. Godbold (1970) claims that secondary school teachers ask even more questions than elementary school teachers do.

It would appear then that questioning is a significant procedure within the classroom in terms of the time spent in questioning activities, but what effect do these questions have on student achievement?

Burton (1962) had listed and supported various functions of questions as follows:

1. stimulating reflective thought by requiring analysis, comparison, definition, interpretation, or the use of judgment;
2. developing appreciations and attitudes;
3. developing the power and habit of evaluation;
4. determining the informational background, interests, and maturity of individuals or class groups; and,
5. creating interest, arousing purpose, or developing a mind set.

Likewise Austin (1963) suggests that teachers use questions for various purposes from developing and maintaining a good emotional and intellectual atmosphere in the classroom to the development of the "act of thinking". Educators agree, questions can serve various educationally desirable functions, but what kinds of questions do teachers ask? What happens in the classroom?

Question Classification Systems and Findings from Their Use

In attempting to categorize the variety of questions asked by teachers, researchers have developed a number of different systems -- many of which are built on the taxonomy developed by Bloom and his associates (1956). McGlathery (1978) summarizes ten commonly used classification systems and there are numerous modifications of each. Questions are classified according to the level of thought required to answer them, the different types of answers that would be acceptable or the way that basic knowledge appears to have been used in arriving at the answer. Indeed, there are numerous systems that have been developed.

In reviewing the literature on the various systems for classifying questions, it was decided that Blosser's Question Category System for Science (1973) would be most appropriate for use in this study. It was developed with particular reference to questions used in science and in science classrooms. The handbook that Blosser had prepared in describing the Question Category System for Science was seen as being particularly useful in training the student teachers involved in this study in the methods of classifying questions and in preparing questions that would represent the various categories.

Blosser's Question Category System for Science

(QCSS) is a relatively simple system which consists of three levels of question classifications. At level I, questions are classified as either "Closed Questions" which seek a limited number of acceptable responses, or "Open Questions" for which there is a wide range of acceptable responses.

The second level of classification further divides the closed and open questions into a total of four subdivisions. The "Closed Questions" can be either cognitive-memory or convergent thinking questions. The cognitive-memory questions are questions where the information for the answers is directly available (textbook, previous lesson or discussion, film, filmstrip, chart, experiment, field trip, etc.). The convergent thinking questions seek answers for which the information is directly available but not in the form called for by the question. The "Open Questions" can be either divergent thinking or evaluative thinking questions. The divergent thinking questions seek answers for which the information is not directly available. The evaluative thinking questions seek answers for which the information may or may not be directly available and imply that the student may be called upon to provide a defense for his response. In addition to the "Open Questions" and "Closed Questions" with their subdivisions, the general categories of "Managerial Questions" and

"Rhetorical Questions" are used.

The third level of the QCSS is based on the type of thinking operation that the questions would require of the respondent. At this level, Blosser indicates that there is no guarantee that the thinking operation which the question is designed to stimulate will produce a particular response in any or all of the students hearing the question. The questions are classified on the basis of their intent as perceived by the listener and not on the basis of the students' response. This is probably a major weakness in most question classification systems. For example, a question which a teacher thinks is designed to produce convergent thinking may only be a Cognitive-Memory Question for a student who has read widely, studied more than the assigned material, or who has previously encountered the question or one similar to it. Nevertheless, Blosser's QCSS lends itself to various levels of classifying teachers' questions where the classifications are not based on detailed analyses of the intents of the questions. For example, questions can readily be classified at Level I (open versus closed questions). At Level II, questions would require a little more analysis during classification into one of the four subdivisions. This level also allows the classification of questions into cognitive memory questions or questions where the response requires some thought (convergent, divergent or evaluative).

Classroom observations of questioning have consistently revealed that teachers tend to ask questions that require simple recall. Gall (1970) reviewed reports of both high school and elementary school teacher questioning strategies where at least two-thirds of the questions asked were factual and one-third of the questions required the students to think. These practices seem to be consistent across subject areas as well as grade levels. Galloway and Mickelson (1973) report that 70 - 80 percent of elementary teacher questions were of the memory variety. Earlier, Parakh (1968) reported that the typical science teacher used memory-recall questions almost exclusively. Such findings prompted Guszak (1967) to conclude "that about the only thing that appears to be programmed into the students is the nearly flawless ability to anticipate the trivial nature of the teachers literal questions" (p. 234). Guszak studied transcriptions of teachers' questions and pupils' responses in primary and elementary classrooms over a three day period. These studies revealed that although 15.3 percent of the questions asked were rated as evaluation, there was serious doubt as to the thinking depth they required since nearly all required 'yes-no' responses that were not supported. Guszak adds that if educators want to condition students for irresponsible citizenship, it seems quite appropriate to ask children for unsupported value statements.

A year later Davis and Tinsley (1968) verified Guszak's findings, only this time among student teachers and their pupils. Both teachers and pupils asked more 'memory' questions during forty-four social studies lessons than all other questions combined. When translation and interpretation categories of questions were combined under the term 'comprehension', no other cognitive objective seemed to have been operational in the forty-four classrooms. Such findings make questionable the adequacy of teacher training in this particular area and demonstrate a need for exploratory studies on the effectiveness of training programs in increasing the effectiveness of student-teacher questioning strategies.

Bruce (1971) indicated that the curriculum may influence the question types used by teachers. He suggested that the use of Science Curriculum Improvement Study (SCIS) materials may cause the teacher to ask more higher level questions. SCIS teaching strategies call for at least three different teaching styles because of the sequencing of lessons. The "exploratory lesson" requires little teacher direction and is designed to allow student manipulation of materials. The "invention lesson" requires the teacher to facilitate student invention of concepts and labels that develop as a result of the exploratory period. The "discovery lesson" is aimed at providing the students the opportunity to apply the new concepts and transfer them to new content areas. It would seem that the invention lesson would call for generally low level questioning, while the discovery lessons would require more higher level questions. Kondo (1968) analyzed the questioning behavior of teachers using the SCIS program to determine the effect that the curriculum and content had on the questions and questioning techniques used. He found that teachers who use complex questioning strategies and patterns tend to use them regardless of the lesson type.

A study by Sloan and Pate (1966) indicated that the curriculum has much to do with teacher questioning behaviors. They found that School Mathematics Study Group (SMSG) teachers asked significantly more higher level questions than those teaching the traditional mathematics programs. They suggested that the reason for this difference was that SMSG materials emphasized the objective of inquiry.

In order for teachers' questions to be effective stimulators of thought, there must first be "an awareness of the various purposes that questions may serve and an awareness of the different types of questions for achieving these purposes", (Pate and Bremer, 1967,

p. 422). In their study they discovered "a surprising number of teachers ... unable to give readily as many as three purposes served by questions" (p. 419). Rogers (1972) also claims that teachers not only lack necessary skills for asking effective questions but also receive little or no guidance in terms of clear strategies set out by either research or training programs related to how effective questioning techniques are developed. While this may be a valid argument for defending classroom practices, it is interesting to determine the effects that training would have upon teacher performance and particular strategies would have on pupils' achievement.

Effects of Questions on Pupil Performance

Attempts to determine relationships between the kinds of questions teachers ask and student performance has been the focus of innumerable studies. Cole and Williams (1973) analyzed audio-tapes of eight different teachers in Grade 2 - 6 and found that cognitive level, length and syntax of pupil response is highly contingent upon the cognitive level of the teachers' questions. Arnold, Atwood and Rogers (1974) report that memory-level questions tend to elicit memory-level responses while questions above that level tend to elicit higher level responses.

Ward and Tikunoff (1976) caution that a teacher's use of higher cognitive questions may not necessarily lead to improved performance for all students, and that the context of the question is more important than how skillfully the teacher asks it. They suggest that student ability levels have much to do with their responses to teacher questions.

Kleinman (1965) investigated this aspect of questioning in an exploratory study involving seventh and eighth grade science teachers and pupils. From observation of twenty-three teachers, three teachers were selected as high in their frequency of asking critical thinking questions and three were selected as low, since their lessons were deprived of such questions. Recordings of questions and answers during four class lessons with each group were made and analyzed. The Test of Understanding Science, Form Jy was administered as a post test. Comparison of performance of the 'high-group' with that of the 'low-group', omitting the low-ability-in-reading pupils, was significant at the 0.01 level of confidence. Adding the low-ability-in-reading pupils changed the significance to the 0.05 level of significance. Kleinman states that "one may cautiously conclude that the high ability pupils ... who have teachers that ask critical thinking questions, have a better understanding of science, of scientists and of the methods of science than the same caliber pupils of teachers who do not ask critical thinking questions" (p. 315).

In a four week study with sixth grade social studies teachers and pupils, Hunkins (1970) found that the group which studied a unit of work through 47 percent analysis and evaluation questions as defined by Bloom's Taxonomy, 1956, showed a significantly higher achievement gain than the group responding to 87 percent knowledge questions. He concluded that use of high level questions helped students not only to evaluate better, but also to improve cognition at lower levels. However, in summarizing experimental studies on questioning, Rosenshine (1976), cited research which reported that low-ability students did best with factual questions and without probing and redirection whereas high-ability students did best with probing and redirection. He suggests that the idea that factual questions are bad and higher cognitive level questions are good, is not supported by well-designed research.

Winne (1979) reviewed 18 experiments which attempted to test the causal relation between teachers' use of higher cognitive questions and student achievement. Of those studies he judged to be reasonably sound methologically, only one contrast out of 18 showed that higher cognitive questions lead to improved achievement relative to lower cognitive questions.

Konya (1973) suggests that the proper mixture of higher-and-lower-level questions seems to be about 50:50. He had teachers control the level of their questions -- different science classes were exposed, respectively, to 65, 50 or 35 percent higher-level questions. He observed that the highest student higher-order response rate appears when the teacher asks equal amounts of higher order and lower order questions.

Studies by Aagard (1974), Ladd and Anderson (1969) and Kleinman (1965) with high school chemistry, earth science and junior high general science classes respectively are consistent with Konya's results. Students of teachers who ask more high-level questions do better on subject matter tests. Perkes (1967) reports that junior high science students exposed mostly to application-type questions achieved higher scores on application questions and lower scores on memory questions than did those exposed largely to memory type questions. Tisher (1971) studied the effects of teacher questioning on student achievement and observed that students exposed to near equal mixtures of higher-and-lower-level questions scored higher on achievement tests than did those exposed to mainly lower-level or higher-level questions.

Gall *et al* (1978) suggest that well-designed questions and strategies may be more important than the level of questions. One such strategy may be the extension of teacher question wait-time, during the questioning activity, particularly with higher-cognitive level questions.

Wait-time and the Questioning Cycle

Bellack (1966) identifies a common questioning cycle within classrooms that is composed of three components: the teacher's question, the pupil's response and the teacher's reaction to the response. Rowe (1969) expands this questioning cycle by the identification of two pause or wait-times. Wait-time I is that period of time between the end of the teacher's question and the beginning of a response or further teacher talk. Wait-time II is that period of time that a teacher waits before replying to a student response. In studying the wait-time aspects of the questioning cycle, Rowe found that experienced teachers allow an average of one second for a child to start an answer before they either repeat the question, rephrase it, often making it a different question or call on another child. After a child makes a response, teachers generally wait slightly less than a second before repeating the child's answer, rephrasing it or asking another question. Arnold, Atwood and Rogers (1973) report that teachers had a short wait-time regardless as to whether the question was simple or complex. In subsequent studies, Arnold, Atwood and Rogers (1974) measured wait-time I in relation to the cognitive level of the questions asked and the cognitive level of the answers given. In this study, the teachers did not control the wait-time and simply asked a question and waited for a student to respond. It was found that the "lapse time" differs by question level and by response level, but the lapse time does not increase directly with the hierarchical level of the questions asked or the responses given. A strong relationship between the question level and the level of the cognitive functioning of the elementary student, as reflected in his level of response, was found. In relation to "lapse-time", the researchers found that when the pupils responded at the analysis level, they took significantly more time to begin their answer than when responses were given at any of the other levels. This study suggests that pupils would use more time if allowed.

Rowe (1974) began a series of studies to determine what would happen if the two wait-times were lengthened to three seconds or more on the average. When mean wait-times of three to five seconds were achieved through training, analysis of more than 900 tapes showed changed values on ten student variables as follows:

1. The length of response increases;
2. The number of unsolicited but appropriate

responses increases;

3. Failures to respond decrease;
4. Confidence as reflected in decrease of inflected responses increases;
5. Incidence of speculative responses increases;
6. Incidence of child-child comparisons of data increases;
7. Incidence of evidence-influence statements increased;
8. The frequency of student questions increases;
9. Incidence of responses from students rated by teachers as relatively slow increases; and,
10. The variety in type moves made by students increases.

In addition to these changed student behaviors, Rowe noted that at least three teacher behaviors changed when wait-time increases as follows:

1. Response flexibility scores increased;
2. Teacher questioning patterns become manageable; and,
3. There is some indication that teacher expectations for performance improves for students rated as relatively slow.

Recently, few researchers have attempted to determine if increased teacher question wait-time effects learning and achievement.

Anderson (1978) studied high school physics pupils' response length, classroom attitudes, science attitudes and achievement in relation to varied teacher question wait-time. He found that the level of student response was congruent with wait-time. However, pupils were more apathetic to school and science in those classes which had longer wait-times. No difference was found when achievement in relation to wait-time was studied.

In studying this relationship, Tobin (1979) attempted to determine if achievement is higher when instruction incorporates a teacher wait-time greater than a threshold of 2.7 seconds and, if the use of an extended teacher wait-time leads to higher achievement for children at the formal stage over those at the concrete stage of cognitive development. During the treatment, 8 teachers maintained a mean wait-time of greater than 2.7 seconds, 5 maintained a wait-time of greater than 1.0 seconds but less than 2.7 seconds and 10 teachers had a wait-time of less than 1.0 second. Science achievement was measured with paper and pencil tests based on the physical science concepts taught in the study. The tests were administered as a pre-test, a midway test and a post-test. The children were identified at the formal operation level by a modified test initially devised by Tisher and Dale (1975). No reliability is given. A repeated measures ANOVA showed significant higher achievement by the extended wait-time group ($p \leq .007$) over the other groups on each post test. A repeated measures ANOVA, with cognitive development as a stratifying independent variable indicated that there was not a significant interaction between wait-time and cognitive development. The use of an extended wait-time was as effective for concrete thinkers as for children able to use formal operations as defined by the tests used.

Riley (1980a), manipulated teacher question wait-time and cognitive levels of teachers' questions and studied achievement as the dependent variable. The cognitive level of questions used in the 30 minute lessons taught by student teachers to grades 2 - 5 pupils were either 100% high, 100% low or a 50/50 percentage. Wait-times, defined as the pause that follows a teacher's question, were assigned at 1, 3 and 5 seconds. The observed average wait-times for the assigned one, three and five second groups were actually 1.17, 3.35 and 5.9 seconds respectively. The pupils took a 25 item achievement test following the teaching period. Ten items were judged to be testing at the knowledge level and fifteen items to be testing at the comprehension level. Riley reports that the pupils assigned to teachers using 5 second wait-times scored significantly higher than did those assigned to student teachers using medium or short wait-times. He also reported that on the knowledge subtest, pupils assigned to teachers using 50% higher cognitive questions scored significantly higher than those using 0% higher cognitive questions ($p < .05$). No significant interactions were found. Riley interpreted that, in terms of student achievement, extended wait-time is as important for low level questions as it is for high level questions.

In summary, learning to incorporate the "pausing principle" or "wait-time" to allow students some time for reflection, a necessary aspect of learning, seems worthwhile. Findings in attempts to determine whether the practice of extended teacher wait-time can effect student learning and achievement are inconclusive and the question remains a very researchable one.

Effects of Training on Teacher Question Wait-Time

Moriber (1971) suggested that one problem which has impeded wait-time research and teacher training is not having an effective method to train teachers to control their wait-time. Subsequently, researchers studying the wait-time principle have used various methods to train teachers to increase their wait-times with varying degrees of success.

Rowe (1974b) reports that 70 to 80% of the elementary teachers she worked with could achieve the criterion wait-time of three seconds by employing three audio-tape teach-reteach cycles accompanied by specific feedback. Rice (1977) investigated whether wait-time, the number of questions asked, and the cognitive level of those questions, would improve if preservice elementary teachers were given instruction dealing with various question asking strategies. Ten elementary education majors were assigned at random to experimental and control groups. The experimental manipulation consisted of viewing films on questioning strategy, reading an article on the importance of wait-time and analyzing ones' own microtaught lessons. In spite of the small sample, significant results were obtained for the three hypotheses. Esquival _et al_ (1978) employed four treatments. Students micro-taught three Science Curriculum Improvement Study lessons. Audiotapes were made and analyzed in one of four ways: (1) self-feedback using a questioning and wait-time critique form, (2) peer feedback, (3) supervisor feed-back, and (4) self-feedback using a form unrelated to questioning. Analysis of subsequent lessons failed to reveal significant differences among the groups with regard to level of question and wait-time. Whether feed-back was provided by a peer, the supervisor or the teachers themselves or no feedback about the behavior was provided, preservice teachers did not differ in their ability to demonstrate the behaviors. The researchers point out that some weaknesses in their design may have allowed some individuals in the treatment group to receive feedback from various sources or not to receive any feedback at all.

DeTure (1979) in a study of 52 preservice elementary teachers set a criterion wait-time of 3.0 seconds. Each teacher was randomly assigned to one of four treatment groups: audio model with no feedback; audio model with feedback; video model with no feedback; and, video model with feedback. Each teacher taught a series of three inquiry lessons to a group of four fourth- or fifth-grade students in a microteaching setting. Prior to a second teaching session, the teacher subjects either viewed a video model of a teacher using the criterion wait-time or listened to the audio portion of the video model. The subjects were also given a short written description of wait-time to help them attend to and focus upon the desired behaviors. Immediately after the model treatment, the teacher subjects taught a second inquiry lesson with instructions to incorporate extended wait-time in their discussions. After one day, the teacher subjects met again to teach a third inquiry lesson. Preceding the third lesson, one-half of each audio and video treatment group were randomly assigned to a feedback or no feedback group. The feedback group listened to and rated their own tapes from the previous session to determine their frequency of achieving the criterion wait-time. The no feedback group read an inquiry related article. All groups were instructed to use extended wait-time for the third lesson. The criterion of 3.0 seconds was not reached by any group for wait-time I. Only in the third teaching session did the wait-time I increase significantly from sessions 1 or 2. Thus, even though her subjects could increase their wait-time as a result of a very short training period, the criterion wait-time of three seconds for wait-time I was not achieved. DeTure suggests that wait-time I is shared by and controlled by both the teacher and the students indicating that the teachers did not practice any specific question asking strategy that might help them increase their wait-time. It may also be that preservice teachers, having numerous other concerns, (Fuller and Bown, 1975), have greater difficulty concentrating on extending their wait-time than inservice teachers. Chewprecha _et al_ (1980) used three training methods to modify questioning and wait-time behaviors of 77 experienced Thai secondary school chemistry teachers. Group I teachers studied from three instructional pamphlets that were mailed to them, one per month for three consecutive months. Group II teachers were mailed three audiotapes with directions to listen to and comment on the types of questions the teacher used in the model lesson. Group III teachers were mailed the same three audiotapes as Group II with directions to listen to and classify the teacher's questions into the category system in which they had been trained. Methods I and II were found to be effective in training teachers to increase the proportion of open questions asked in their classrooms. Only Method I was effective in training the teachers to improve their wait-time.

From the few studies that describe training methods used to assist teachers in increasing their wait-time, it appears that when teachers are provided with a question asking strategy and information as to what can be expected when question wait-time increases, their wait-time usually increases.

Summary

Educators agree that questioning and questions are among the most commonly used teaching strategies. The various question classification system that have been developed to identify questions are based on the intent of the question, and there does not seem to be any guarantee that a specific question stimulates the particular cognitive functioning in a respondent for which it may have been intended. With the use of different categorization systems, it is found that teachers tend to ask low cognitive level questions. Research attempting to relate higher cognitive level questions and achievement has not been conclusive. However, there is some indication that higher and lower cognitive level questions in approximately equal proportions increases student achievement.

Results from classroom observations indicate that regardless as to whether teachers ask higher or lower cognitive level questions, they expect students to begin answering their questions within a very short period of time. When this "wait-time" is increased, teachers can expect increases in some desirable student and teacher classroom behaviors.

Research attempts at relating increases in teacher question wait-time to student achievement are few and inconclusive. Studies in this area are highly dependent on effective training procedures to assist teachers in extending their wait-time. Various training methods have been used with both experienced and preservice teachers with varying degrees of success.

CHAPTER III

EXPERIMENTAL PROCEDURES AND DESIGN

Organization of the Chapter

This chapter is presented in seven sections and outlines the experimental procedures for gathering the data to test the research hypotheses. Section one identifies the experimental research design that is used. The second section identifies the various purposes served by the pilot study completed during the university term immediately prior to the study. Section three describes the pilot and main study student teacher and student samples. Section four describes the development and final edition of the instruments used, and the methods of data collection. Section five details the development, refinement and description of procedures associated with the presentation of treatments during the study. Section six presents the finalized design matrix based on the number of student teachers who were able to achieve criterion success levels with each treatment group, and the methods for the statistical analyses of the data. Section seven briefly summarizes the contents of the chapter

The Design

The nonequivalent control group design outlined by Campbell and Stanley (1966), was used for this study and is diagrammed as follows:

$O_1 - X_1 - O_2 - O_3$

$O_4 - X_2 - O_5 - O_6$

Where:

X_1 refers to instruction of a 60 minute instructional unit on science, society, and technology by student teachers to grade XI biology 20 students where the student teachers used a higher cognitive level question wait-time range of 1-4 seconds;

X_2 refers to instruction of a 60 minute instructional unit on science, society, and technology by the same student teachers to grade XI biology 20 students where the student teachers used a higher cognitive level question wait-time range of 4-7 seconds;

O_1 and O_4 refers to the administration of an achievement test on the Alberta Biology 10 Curriculum cognitive objectives;

O_2 and O_5 refers to the administration of an achievement test on the science, society, and technology instructional unit objectives; and,

O_3 and O_6 refers to the administration of the Student Appraisal of Student Teacher questionnaire.

Seventeen biology student teachers were initially involved in the research. During the study, two student teachers withdrew from their programs of studies at the University. Eight of the remaining fifteen were successful in achieving the criterion wait-time ranges for at least 70 percent of the higher cognitive level questions asked of each treatment group during the presentation of the instructional unit.

Fifteen grade XI (biology 20) students were randomly sampled from each of the sixteen classes taught by the eight student teachers who successfully achieved the criterion wait-time ranges. Thus, the final sample of students consisted of 120 students in each treatment group who were in attendance during the treatments and had completed responses to both achievement tests and the appraisal of student teacher questionnaires.

The Pilot Study

A pilot study, which was completed during the fall semester, 1980, was essential to the study in order to delimit, delineate and refine the various instruments, techniques and procedures for use in the study. Specifically, the purpose of the pilot study was, as follows:

1. Insure the validity and reliability of the covariate test items;

2. Develop, pilot, and item analyze an achievement test that would be a valid and reliable dependent variable measure;
3. Develop, pilot, and analyze the results of a Likert scale questionnaire to be used as a student appraisal of their student teacher's effectiveness;
4. Determine whether Blosser's (1973), Question Category System for Science (Q.C.S.S.) is a functional and reliable system for distinquishing questions requiring recall from those requiring higher thought processes;
5. Develop, pilot, and subsequently revise, as appropriate, an instructional unit to be used in the study by student teachers to teach concepts of the interrelationships of science, society and technology;
6. Develop a training program to assist student teachers in developing a question asking strategy that would allow them to use different question wait-time ranges effectively;
7. Develop and refine a reliable procedure for accurately measuring teacher question wait-times; and,
8. Determine the level of success that can be expected of student teachers in achieving

specific question wait-time ranges.

Details of the pilot study procedures and findings are included in subsequent sections of this chapter.

Samples

Pilot Study and Research Study Student Teacher Samples

The student teachers involved in the pilot and main studies were biological science student teachers in the phase III program at the University of Alberta. The pilot study student teacher sample consisted of four volunteers from the 1980 fall term class. The research study student teachers initially consisted of the entire class of seventeen biology student teachers enrolled in the phase III program during the winter term, 1981.

All student teachers in this program had satisfactorily completed five weeks of school based experiences as follows:

1. The equivalent of one week consisted of classroom observation and small group instruction activities during ten half-day visitations to at least two different schools over a 14 week period. Associated with these school based activities were on-campus seminars which attempted to integrate the school based experiences with educational theory; and,
2. Four weeks of student teaching in which the

student teacher prepares, presents and analyzes individual lessons. In this phase, student teachers attempt to arrange for a plan, teach, analyze, revise, reteach and analyze series of experiences when the student teacher has an opportunity to teach the same content to at least two different classes. During this student teaching experience, student teachers teach an average of 20 individual lessons at the junior high school level.

The phase III biology teacher education program consists of the following five courses:

1. Ed. C.I. 370 - Curriculum and Instruction in Secondary School - Biological Science I;
2. Ed. C.I. 371 - Curriculum and Instruction in Secondary School - Biological Science II;
3. Ed. Pr. 355 - Student Teaching in the Secondary School - III;
4. Ed. Pr. 356 - Student Teaching in the Secondary School - III; and,
5. Ed. Pr. 354 - Campus Based Practicum (Secondary Education)

The courses are taken over a 14 week, fall or winter term and are sequenced as follows:

1. Weeks 1-3 include Ed. C.I. 370 and Ed. Pr. 354. Ed. C.I. 370 consists of 15 hours of classes per week in addition to approximately 15 hours of independent study modules aimed at preparing the student teachers for student teaching at the junior high school level, (Ed. Pr. 355). Ed. Pr. 354 consists of two or three 15-20 minute on-campus peer-teaching sessions and subsequent appraisals.
2. Weeks 4-7 consists of Ed. Pr. 355 which involves student teaching at the junior high school. The student teachers are at school full time, except for two half-day call-back seminar sessions which occur during weeks four and six.
3. Weeks 8-10 include Ed. C.I. 371 and Ed. Pr. 354. Ed. C.I. 371 consists of 15 hours of classes per week in addition to approximately 15 hours of independent study modules aimed at preparing the student teachers for student teaching at the senior high school level, (Ed. Pr. 356). Ed.Pr. 354 consists of two or three 15-20 minute on-campus peer-teaching sessions and subsequent appraisals.
4. Weeks 11-14 consists of Ed. Pr. 356 which involves student teaching at the senior high school. As with Ed. Pr. 355, the student

teachers are at school full time, except for two half-day call-back seminar sessions which occur during weeks 11 and 13.

During each round of student teaching, there is a different cooperating teacher working with each student teacher. There is also a faculty consultant who works closely with each student teacher and their cooperating teacher during both rounds. During each round of student teaching in phase III, the student teacher:

1. attempts a variety of teaching methods during the development of various teaching skills, and begins to develop an individual teaching style;
2. prepares written lesson plans on a daily basis, and shares them with the cooperating teacher and faculty consultant;
3. prepares and teaches entire instructional units in the area of specialization;
4. becomes involved in co-curricular and extra-curricular activities; and,
5. participates with analyses of his/her teaching, with the cooperating teacher and faculty consultant, particularly during the preparation of the mid-point progress report at the end of the second week of each round.

During the student teaching rounds, each student teacher is supervised and assisted by his/her cooperating teacher and faculty consultant in all aspects of their experiences in the school. In addition to the midpoint progress reports referred to in item 5, student teachers receive final progress reports, and recommendations for employment from their cooperating teachers and from their faculty consultants at the end of each round.

Both pilot study and research study student teachers had considerable involvement in many facets of the study. The pilot study student teachers were involved as follows:

1. Development of a training program in the use of the Question Category System for Science, (Blosser, 1973);
2. Development and pilot teaching of an instructional unit on science, society and technology; and,
3. Development of a procedure to assist research study student teachers in developing a question asking strategy that would allow them to use different question wait-time ranges effectively.

The pilot study student teachers also provided the investigator with an indication of the success levels that can be expected of student teachers in achieving 1-4 and 4-7 second higher cognitive level question wait-time ranges.

The research study student teachers were involved as follows:

1. They studied the Question Category System for Science, (Blosser, 1973), and practiced using it;
2. They each taught the instructional unit on science, society and technology to each of two treatment groups of grade XI biology 20 students. They used a 1-4 second higher cognitive level question wait-time range with one group and a 4-7 second higher cognitive level question wait-time range with the other group;
3. They audiotaped their treatment group lessons, transcribed, and categorized the question asked as low and high cognitive level question according to the Question Category System for Science, (Blosser, 1973);
4. They administered the achievement test on science, society, and technology to each treatment group; and,
5. They administered the student appraisal of student teacher questionnaire.

Details of the involvements of both pilot study and research study student teachers are presented in subsequent sections of this chapter.

Pilot Study and Research Study Student Samples

Grade XI (biology 20) students from Edmonton area senior high schools who were taught by cooperating teachers were involved in the pilot and main studies.

In the pilot study, the responses of all students who had completed all instruments, and were present for the entire treatment, were used for subsequent analyses.

In the main study, the responses of fifteen students who had attended class during the presentation of the instructional unit used in the treatment, and completed all instruments, were randomly selected from each class, where the student teacher achieved the criterion wait-time range for at least 70 percent of the higher cognitive level questions asked and used for subsequent statistical analyses.

Instrumentation

The covariate achievement test was administered to all students in both the pilot and research studies at the beginning of the school semester which was approximately nine weeks in advance of the presentation of the treatment lessons.

The posttest on science, society and technology which was aimed at determining the treatment groups' achievement of instructional unit objectives was administered to all treatment groups during the class period following the presentation of the unit.

The Likert scale student appraisal of student teacher questionnaire consisted of items designed to determine the teaching and question asking effectiveness of the student teachers during the presentations of the instructional unit. It was administered immediately after the posttest on science, society and technology achievement test.

<u>The Covariate Achievement Test</u>

Initially, it was planned that the biology 10 curriculum test items from the <u>Alberta Biology Achievement Test - Form B</u> would be used in the preparation of this test. However, when these test items were perused by five experienced biology teachers, they indicated that, of the 35 biology test items, 12 items would not be valid because of changes in the biology 10 curriculum which had occurred since the development of the achievement test. These biology teachers further agreed that the remaining 23 items did not represent the total biology 10 program. Thus, it became necessary to develop a covariate achievement test by adding test items to the 23 valid items from the <u>Alberta Biology Achievement Test - Form B</u>.

The procedures used, with an aim toward the development of a reliable covariate achievement test with a high level of content validity, were as follows:

1. Seventy-seven biology 10 achievement test items representing the objectives of the biology 10 program were prepared.
2. Five experienced biology teachers independently studied the 77 items and identified those which they considered to be most valid and suggested specific revisions that would increase the content validity of the other items.
3. A 55 item pilot study covariate achievement test was prepared (see appendix A), consisting of 23 items from the Alberta Biology Achievement Test - Form B, and 32 of the 77 items prepared by the investigator and deemed to be valid by the five biology teachers. Table I presents a listing of the Alberta biology 10 program objectives and the pilot study test items aimed at determining achievement of each objective.
4. Five additional experienced biology teachers, who served as cooperating teachers during the pilot study, perused the 55 item pilot study test. They suggested certain changes to some items in order to improve the content validity of the test. They also suggested that some items should be deleted.

TABLE I

CATEGORIZATION OF PILOT STUDY COVARIATE TEST ITEMS ACCORDING TO BIOLOGY 10 PROGRAM OBJECTIVES

Biology 10 Program Objectives	Suggested Instructional Time (Hours)	Test Items
1. To promote understanding and development of research skills by carrying out a project	10-15	14,15,46,47, 48,49,50,51, 52,53,54,55
2. To study the principles of cell biology	5-10	1,2,8,17,20 21,22,23,38, 39,40,41
3. To gain a better understanding of the principles of classification 4. To learn reasons for and techniques of collecting and maintaining appropriate biological specimens and to develop an appreciation of the importance of these activities 5. To study the development and relationship of form, function and role in nature of the groups of life forms during the comparative study of representations of the biological kingdom	40-50	3,4,5,6,7,9, 10,11,12,13, 16,18,19,24, 25,26,27,28, 29,30,31,32, 33,34,35,36, 37,42,43,44, 45
Total	65	

5. The pilot study student responses to the test were submitted to test item analysis by the documented *Itemanal R198 program in Computing Services at the University of Alberta, (see appendix C for a sample of the print-out provided by the program). Table II presents the pilot study covariate achievement test statistics.

TABLE II

PILOT STUDY COVARIATE ACHIEVEMENT TEST STATISTICS

N	Mean	Variance	Standard Deviation	KR-20 Reliability	Standard Error Of Measurement
210	27.09	40.32	6.35	0.7307	3.2953

6. Pilot study test items which were perceived to be lacking in content validity, as judged by the pilot study cooperating teachers, or which had apparent weaknesses according to the item analysis were either deleted or revised. Table III presents a summary of the pilot study covariate test item analysis and presents the decisions as to whether each item was replaced, deleted, revised or kept for the development of

the research study covariate achievement test.

TABLE III

SUMMARY OF PILOT STUDY COVARIATE TEST ITEM ANALYSIS AND DECISIONS REGARDING REVISIONS OR REPLACEMENTS OF ITEMS

Item Number: Pilot Test	Item Number: Revised Test	Difficulty Index	Biserial Correlation Coefficient	Item Reliability Index	Decision
1	1	.500	.267	.106	Replace
2	2	.629	.327	.124	Keep
3	3	.586	.286	.111	Keep
4	4	.867	.590	.127	Keep
5	5	.395	.559	.215	Keep
6	6	.733	.253	.083	Keep/Valid
7		.367	.214	.081	Delete
8		.662	.302	.110	Delete
9	7	.833	.486	.121	Keep
10	8	.395	.500	.193	Keep
11	9	.443	.532	.210	Keep
12	10	.614	.331	.127	Keep
13	11	.357	.411	.153	Keep
14	12	.343	.326	.120	Keep
15	13	.738	.382	.124	Keep
16	14	.486	.412	.164	Keep
17		.395	.181	.070	Delete
18	15	.429	.581	.228	Keep
19	16	.638	.421	.158	Keep
20	25	.490	.188	.075	Replace
21		.252	.083	.027	Delete
22		.729	.475	.157	Delete
23		.181	.293	.077	Delete
24	17	.210	.053	.015	Revise
25	18	.400	.333	.129	Keep
26	19	.219	.338	.100	Keep/Valid
27	20	.495	.318	.127	Keep
28	21	.543	.362	.143	Keep
29	22	.333	.217	.079	Replace
30	23	.333	.258	.094	Replace
31	24	.419	.281	.110	Replace
32		.210	.378	.109	Delete
33		.248	.125	.039	Delete
34		.857	.414	.093	Delete
35		.214	.252	.161	Delete

TABLE III - continued

Item Number		Difficulty Index	Biserial Correlation Coefficient	Item Reliability Index	Decision
Pilot Test	Revised Test				
36		.162	.104	.026	Delete
37	26	.562	.420	.166	Keep
38		.048	.364	.036	Delete
39	27	.414	.332	.129	Keep
40	28	.338	.482	.176	Keep
41	29	.881	.566	.113	Keep
42		.833	.174	.043	Delete
43	30	.319	.288	.103	Keep
44	31	.771	.593	.179	Keep
45	32	.829	.372	.095	Keep
46	33	.690	.407	.144	Keep
47		.548	.121	.048	Delete
48	34	.586	.403	.157	Keep
49		.305	.057	.020	Delete
50	35	.710	.502	.172	Keep
51	36	.586	.282	.110	Keep
52	37	.505	.220	.088	Keep/Valid
53	38	.629	.503	.190	Keep
54	39	.348	.519	.192	Keep
55	40	.481	.225	.090	Keep/Valid

As indicated in table III, the revised covariate achievement test has 40 items, (see appendix B). Table IV presents the Alberta biology 10 program objectives and the numbers of test items which are associated with determining achievement of each program objective. It also summarizes the amounts of instructional time that is suggested for each topic area and reveals that the number of research study covariate achievement test items for each topic area is proportionate to the instructional time usually devoted to studies in that topic area.

TABLE IV

CATEGORIZATION OF COVARIATE TEST ITEMS ACCORDING TO BIOLOGY 10 PROGRAM OBJECTIVES

Biology 10 Program Objectives	Suggested Instructional Time (Hours)	Test Items
1. To promote understanding and development of research skills by carrying out a project.	10-15	12,13,33,34, 35,36,38,39, 40
2. To study the principles of cell biology	5-10	1,2,22,27, 28,29,37
3. To gain a better understanding of the principles of classification)		
4. To learn reasons for and techniques of collecting and maintaining appropriate biological specimens and to develop an appreciation of the importance of these activities)	40-50	3,4,5,6,7,8, 9,10,11,14, 15,16,17,18, 19,20,21,23, 24,25,26,30, 31,32
5. To study the development and relationship of form, function and role in nature of the groups of life forms during the comparative study of representations of the biological kingdom)		
Total	65	

7. During the research, sixteen research study cooperating teachers provided comments regarding the content validity of the revised covariate achievement test which indicated that they judged the test to be valid in terms of the biology 10 program at their schools.

8. Two hundred and forty student response sheets for the covariate achievement test were submitted to test item analysis by the documented *Itemanal R198 Program in Computing Services at the University of Alberta, (see appendix C for the print-out of a sample of items from the analysis). Table V presents the research study covariate achievement test statistics.

TABLE V

RESEARCH STUDY COVARIATE ACHIEVEMENT TEST STATISTICS

N	Mean	Variance	Standard Deviation	KR-20 Reliability	Standard Error Of Measurement
240	22.73	26.43	5.14	0.695	2.84

The Kuder-Richardson 20 coefficient of reliability reported in table V indicates that the test is relatively reliable. The summary of the research study covariate achievement test item analysis presented in table VI indicates that the items have a broad range of difficulty and relatively high biserial correlations.

TABLE VI

SUMMARY OF COVARIATE TEST ITEM ANALYSIS

Test Item	Difficulty Index	Biserial Correlation	Item Reliability Index
1	.354	.248	.092
2	.658	.245	.090
3	.487	.417	.166
4	.871	.519	.109
5	.408	.572	.222
6	.662	.378	.138
7	.896	.450	.081
8	.479	.530	.211
9	.592	.350	.136
10	.625	.464	.176
11	.458	.495	.196
12	.254	.425	.136
13	.754	.309	.097
14	.479	.447	.178
15	.575	.504	.198
16	.742	.498	.161
17	.267	.274	.090
18	.475	.343	.136
19	.300	.460	.160
20	.475	.225	.089
21	.542	.296	.117
22	.700	.312	.108
23	.450	.530	.210
24	.717	.423	.143
25	.358	.571	.213
26	.542	.428	.170
27	.492	.231	.092
28	.350	.344	.128
29	.954	.431	.041
30	.292	.070	.024
31	.767	.405	.124
32	.858	.394	.088
33	.779	.412	.122

TABLE VI - continued

Test Item	Difficulty Index	Biserial Correlation	Item Reliability Index
34	.717	.440	.149
35	.675	.151	.054
36	.612	.123	.047
37	.583	.233	.091
38	.646	.249	.093
39	.346	.224	.083
40	.542	.447	.177

The Science, Society and Technology Achievement Test

The development of a 40 objective item test, to measure student achievement of the instructional unit on science, society and technology behavioral objectives, occurred in conjunction with the development of the outline for teaching the instructional unit. The procedures used in an attempt to develop a reliable achievement test with a high level of content validity were as follows:

1. Forty objective test items were constructed to measure student achievement of the 12 behavioral objectives and five main concepts which were prepared as a guide to assist student teachers in presenting the unit on science, society and technology during the pilot study. See appendix D for the pilot study test and appendix M for the pilot study instructional unit concepts

and objectives.

2. Copies of the pilot study instructional unit outline, and associated achievement test were distributed to two science teacher educators and three science education graduate students at the University of Alberta in Edmonton for validation purposes. They were requested to match each test item with the objective or objectives that would be tested by the item. Their classifications, summarized in table VII, indicate that they perceived many test items to be measuring achievement of more than one objective, and that the test measured achievement of all objectives.

TABLE VII

SUMMARY OF PILOT STUDY INSTRUCTIONAL UNIT OBJECTIVES MATCHED WITH PILOT STUDY ACHIEVEMENT TEST ITEMS

Instructional Unit Objectives	Test Items
a. define technology, as opposed to science, as used by man	1, 6, 7, 25, 32, 33, 35
b. describe the uses of fire	2, 3, 15, 26
c. describe the consequences of man developing the use of fire	2, 3, 15, 26
d. identify and explain the uses of fire as a functioning of the processes of science	6, 32, 33, 35

TABLE VII - continued

Instructional Unit Objectives	Test Items
e. illustrate (describe) the dependency that man has developed for fire	2, 3, 15, 26
f. justify the statement: "Problems of a present technology may only be alleviated through further advances in technology	9, 11, 13, 28, 30
g. cite and describe agriculture as a result of major technological advances	4, 14, 16, 24
h. identify and explain the discovery of agriculture as a means of the functioning of the processes of science	6, 32, 33, 35
i. describe the consequences of man's use of agriculture	4, 16, 17, 21, 23, 29, 31, 36, 39
j. explain the dependency that man has developed for agriculture	4, 16, 21, 22, 23, 29, 31, 36
k. explain how continued technological advances in agriculture were a part of man's cultural history	16, 21, 31, 36
l. evaluate the effects of science and major technological advances on society, science and technology	5, 8, 10, 12, 18, 19, 20, 21, 22, 27, 28, 31, 34, 35, 36, 37, 38, 40

3. During the pilot study, the student teachers taught the unit on science, society, and technology to the treatment groups prior to having an opportunity to peruse the achievement test items. While the test was administered to

the treatment groups, the student teachers studied the test items for content validity in terms of what they had taught or discussed during their lessons. They indicated that the items were valid in that they could be answered correctly if students comprehended class discussions or extended the logic developed during the class discussions.

4. The five pilot study cooperating teachers observed their student teachers during the presentation of the treatment lessons, and studied the unit outline, (see appendix M), and achievement posttest, (see appendix D). They reported that the pilot study achievement test items were valid in terms of their student teachers' presentations.

5. The pilot study student responses to the achievement posttest were submitted to test item analysis by the documented *Itemanal R198 Program in Computing Services at the University of Alberta, (a sample of the item analysis provided by this program is presented in appendix E). Table VIII presents the pilot study posttest statistics and table IX includes a summary of the pilot study posttest item analyses.

TABLE VIII

PILOT STUDY SCIENCE, SOCIETY AND TECHNOLOGY ACHIEVEMENT TEST STATISTICS

N	Mean	Variance	Standard Deviation	KR-20 Reliability	Standard Error of Measurement
183	24.02	17.85	4.23	.536	2.88

TABLE IX

SUMMARY OF PILOT STUDY POSTTEST ITEM ANALYSIS AND DECISIONS REGARDING REVISIONS OR REPLACEMENTS OF ITEMS

Item Number		Difficulty Index	Biserial Correlation Coefficient	Item Reliability Index	Decision
Pilot Test	Revised Test				
1	51	.721	.215	0.072	Revise
2	52	.749	.198	0.063	Revise
3	53	.803	.245	0.068	Revise
4	54	.792	.545	0.156	Keep
5	55	.464	.471	0.187	Keep
6	56	.497	.248	0.099	Revise
7	57	.503	.394	0.157	Keep
8	58	.634	.128	0.048	Revise
9	59	.585	.203	0.079	Replace
10	60	.574	.314	0.123	Replace
11	61	.202	.158	0.044	Replace
12	62	.623	.120	0.045	Replace
13	63	.716	.247	0.024	Replace
14	64	.902	.278	0.048	Replace
15	65	.617	.421	0.161	Keep
16	66	.525	.066	0.026	Revise
17	67	.727	.450	0.150	Keep
18	68	.847	.353	0.124	Keep
19	69	.481	.378	0.151	Keep
20	70	.514	.316	0.146	Keep
21	71	.721	.315	0.106	Keep
22	72	.656	.432	0.159	Keep

TABLE IX - continued

Item Number		Difficulty Index	Biserial Correlation Coefficient	Item Reliability Index	Decision
Pilot Test	Revised Test				
23	73	.503	.365	0.145	Keep
24	74	.552	.295	0.117	Keep
25	75	.749	.369	0.147	Keep
26	76	.525	.261	0.104	Keep
27	77	.301	.253	0.088	Keep
28	78	.344	.320	0.118	Keep
29	79	.454	.299	0.119	Keep
30	80	.749	.389	0.124	Keep
31	81	.825	.485	0.125	Keep
32	82	.497	.105	0.042	Revise
33	83	.541	.203	0.081	Keep
34	84	.404	.356	0.138	Keep
35	85	.891	.562	0.105	Replace
36	86	.536	.372	0.148	Keep
37	87	.639	.401	0.150	Keep
38	88	.333	.142	0.052	Revise
39	89	.749	.531	0.169	Keep
40	90	.574	.384	0.150	Keep

The Kuder-Richardson 20 coefficient of reliability of 0.536 is minimally acceptable, and the summary of the test item analyses presented in table IX indicates that a number of items have relatively low biserial correlations and item reliability indices. In an attempt to increase item and test reliabilities, prior to using the posttest in the research study, it was decided to replace some items and revise others. The seven items selected to be replaced were those which had low reliabilities or were included in a set of items which had low reliabilities. The eight items selected for revision were those which had low reliabilities and weaknesses in the alternatives as identified by the individual item analysis test score means for the alternatives and discriminating power values, (see appendix F for a sample item analysis). The pilot study student teacher experiences during the presentation of the treatment lessons, and associated revisions in the instructional unit, provided the bases for the development of replacement items which would maintain content validity. After the pilot study student teachers presented their treatment lessons, they indicated that the class discussions during treatments frequently related to more than one instructional objective simultaneously, i.e., some objectives were inclusive of others. As a result of these experiences, confirmed by the audiotape recordings of their lessons, they recommended that both the main concepts and the behavioral objectives given in the pilot study instructional unit outline, (see appendix M) should be mutually exclusive of each other and reduced in number. The instructional unit outline was changed in response to these recommendations, (details of the changes are presented in a subsequent section of this chapter). The seven replacement items were developed in response to the changes in the instructional unit.

6. A further attempt was made to insure fidelity between the revised instructional unit, (see appendix N), and the revised science, society and technology posttest, (see appendix E). Copies of the revised instructional unit outline and revised science, society and technology posttest were distributed to two science teacher educators and three science education graduate students at the University of Alberta for validation purposes. They were requested to match each test item with the instructional unit objective or objectives that would be tested by the item. Their decisions presented in table X indicate that they perceived each test item to be quite specific in testing for achievement of only one objective, and that the test would determine achievements of all objectives in the instructional unit outline.

TABLE X

SUMMARY OF RESEARCH STUDY INSTRUCTIONAL UNIT OBJECTIVES MATCHED WITH ACHIEVEMENT TEST ITEMS

Instructional Unit Objectives	Test Items
a. define technology	51, 64, 83
b. describe various positive and negative effects that technological advances have on society (past, present and future)	52, 53, 63, 65, 66, 69, 71, 72, 73, 74, 76, 81, 86
c. describe societal (cultural) evolution in relation to technological advances	54, 55, 58, 77, 78
d. define science	56, 83, 85
e. describe man's discoveries and uses of technologies in terms of: i) his traits, and ii) his societal needs	57, 75, 82, 88
f. interpret the statement: "Problems of a technology may be alleviated through further advances in the technology"	61, 80
g. interpret, analyze and predict the effects of a major technological advance on society, science and technology, (past, present or future)	59, 60, 62, 67, 68, 70, 79, 84, 87, 89, 90

7. The fifteen research study student teachers similarly analyzed the items of the post-test on science, society and technology with regard to their validity in terms of the treatment presentations. They indicated that

the items were valid in that they measured student achievement relative to class instruction.

8. The fifteen research study cooperating teachers observed their student teachers during the treatment lessons, and indicated that the test items were valid in terms of class instruction and the instructional unit objectives.

9. Two hundred and forty research study student response sheets for the science, society and technology achievement test were submitted to test item analysis using the *Itemanal R198 Program in Computing Services at the University of Alberta, (see appendix F for a printout of a sample of items from this analysis). The test statistics are presented in table XI and a summary of the item analysis is presented in table XII. The Kuder-Richardson 20 coefficient of reliability of 0.52 was found and is reported in table XI. The summary of the item analysis, presented in table XII, indicates that the items have a broad range of difficulty and varied biserial correlations.

TABLE XI

RESEARCH STUDY SCIENCE, SOCIETY AND TECHNOLOGY ACHIEVEMENT TEST STATISTICS

N	Mean	Variance	Standard Deviation	KR-20 Reliability	Standard Error of Measurement
240	23.62	17.37	4.17	.52	2.888

TABLE XII

SUMMARY OF SCIENCE, SOCIETY AND TECHNOLOGY ACHIEVEMENT TEST ITEM ANALYSIS

Test Item	Difficulty Index	Biserial Correlation	Item Reliability Index
51	.537	.148	.059
52	.662	.143	.052
53	.733	.261	.086
54	.883	.456	.089
55	.450	.402	.159
56	.637	.408	.153
57	.592	.265	.103
58	.796	.213	.060
59	.787	.595	.173
60	.525	.266	.106
61	.642	.242	.090
62	.742	.277	.089
63	.179	.078	.020
64	.696	.130	.045
65	.600	.276	.107
66	.662	.198	.072
67	.750	.334	.106
68	.196	.361	.100
69	.392	.439	.169
70	.592	.393	.153
71	.646	.376	.140
72	.608	.412	.158

TABLE XII - continued

Test	Difficulty Index	Biserial Correlation	Item Reliability Index
73	.462	.368	.146
74	.537	.392	.156
75	.700	.126	.044
76	.542	.230	.091
77	.233	.141	.043
78	.400	.089	.034
79	.433	.121	.047
80	.808	.508	.139
81	.833	.536	.134
82	.479	.124	.050
83	.546	.325	.129
84	.408	.343	.133
85	.729	.224	.074
86	.533	.381	.151
87	.742	.323	.104
88	.646	.346	.129
89	.742	.329	.106
90	.537	.420	.167

Student Appraisal of Student Teacher Questionnaire

An important aspect of the classroom teacher-student relationship is the student perception of the teaching-learning processes. To determine the student perceptions of their student teachers in relation to their teaching effectiveness and questioning strategies used, a student appraisal form consisting of 25 likert scale items was prepared for the pilot study (see appendix G).

The statements included in the student appraisal of student teacher questionnaire were developed in response to a review of the literature.

Five factors reported by Trent and Cohen (1973), to be consistently identified by students, as major factors of affective teaching were selected as the bases for the development of the questionnaire statements pertaining to teaching effectiveness. The five factors are as follows:

1. Clarity of organization, interpretation and explanation;
2. Encouragement of class discussion;
3. Stimulation of students' interests, motivation and thinking;
4. Manifestation of attentiveness to and interest in students; and,
5. Manifestation of enthusiasm.

The following student appraisal of student teacher teaching effectiveness statements were prepared to reflect the five major factors of effective teaching:

1. The student teacher seemed to be friendly;
2. I was interested in the lesson;
3. The student teacher explained the lessons clearly;
4. The student teacher enjoyed teaching our class;
5. I did not understand what the student teacher was talking about;
6. The student teacher listened carefully to our answers;

7. The student teacher used our answers in the discussion;
8. I was free to disagree with the student teacher;
9. The student teacher clearly explained what was planned;
10. The student teacher "picked on" some people in our class;
11. The student teacher was enthusiastic;
12. The student teacher made good use of class time;
13. The student teacher was well prepared for the lesson, and,
14. I learned a lot during the lesson.

A perusal of the literature on effective use of questions revealed various criteria that were consistent among authors. The criteria of effective questioning identified by Blosser (1973), Brown (1975), Cohen and Morris (1977), Cooper _et al_ (1977), Houston (1938), Orlich _et al_ (1980), and Stones and Morris (1977), were selected to be used as the bases for the development of statements for the student appraisal of student teacher questioning effectiveness. Specifically, the criteria used are as follows:

1. Questions should be directly related to the instruction;
2. Questions should be adapted to the knowledge, maturity and experiential background of the

students;

3. Questioning should allow some success for bright, dull, and average ability students;
4. Questioning should assist students in developing efficient study habits;
5. Questioning should keep the subject developing;
6. Questions should be adapted to the student's interest;
7. Questions should be so formulated as to cause the student to avoid guessing;
8. There should be a logical sequence of questions;
9. Questioning should permit time for the organization of thought;
10. The questions should challenge the concentrated attention of the entire class;
11. The treatment of sincere responses should be tolerant, open minded, courteous and tactful. Particular care should be exercised to avoid inhibitions; and,
12. Questions should, whenever possible, demand the use of facts in their relationships, i.e., demand organization of thought.

The following student appraisal questionnaire statements were prepared to reflect the criteria of effective questioning:

1. The student teacher asked questions that tested

our memory;

2. The student teacher asked questions that made me think;
3. I did not have enough time to think of answers to the questions asked;
4. The questions asked helped me learn;
5. I was afraid to try and answer the student teacher's questions;
6. The student teacher helped us reason out answers to difficult questions;
7. The student teacher gave everyone a chance to answer questions;
8. The student teacher encouraged everyone to ask questions;
9. The student teacher criticized our answers to his/her questions; and,
10. The student teacher clearly explained how he/she would teach.

The statements pertaining to questioning effectiveness and teaching effectiveness were included in the pilot study student appraisal of student teacher questionnaire (see appendix G).

Copies of the questionnaire statements, factors of effective teaching and criteria of effective questioning were distributed to two science teacher educators and three science education graduate students at the University of Alberta. They were requested to match the questionnaire statements with the factors of effective teaching and criteria of effective questioning. Each member of the group indicated that the questionnaire statements related to more than one factor of effective teaching and to more than one criterion of effective questioning. This was not surprising since each factor of effective teaching and each criterion of effective questioning are quite comprehensive. The results of their matchings are presented in tables XIII and XIV.

TABLE XIII

FACTORS OF EFFECTIVE TEACHING MATCHED TO THE PILOT STUDY STUDENT APPRAISAL QUESTIONNAIRE STATEMENTS

Factors of Effective Teaching	Item Numbers of Questionnaire Statements
Clarity of organization, interpretation and explanation	5, 9, 16, 21, 24
Encouragement of class discussion	1, 3, 11, 13, 14, 17
Stimulation of students' interests, motivation and thinking	1, 3, 11, 13, 14, 17, 25
Manifestation of attentiveness to and interest in students	1, 3, 7, 11, 13, 14, 17
Manifestation of enthusiasm	1, 7, 11, 17, 20

TABLE XIV

CRITERIA OF EFFECTIVE QUESTIONING MATCHED TO THE PILOT STUDY STUDENT APPRAISAL STATEMENTS

Criteria of Effective Questioning	Item Numbers of Questionnaire Statements
Questions should be directly related to the instruction	8, 10, 12, 19, 23
Questions should be adapted to the knowledge, maturity and experiential background of the students	2, 10, 12
Questioning should allow some success for bright, dull, and average ability students	2, 4, 12, 19
Questioning should assist students in developing efficient study habits	8, 10, 12, 19, 23
Questioning should keep the subject developing	4, 8, 10, 12, 19
Questions should be adapted to the student's interest	2, 6, 23
Questions should be formulated as to cause the student to avoid guessing	4, 6, 8, 12
There should be a logical sequence of questions	8, 10, 12
Questioning should permit time for the organization of thought	6, 8, 10, 12
The questions should challenge the concentrated attention of the entire class	4, 6, 10, 12
The treatment of sincere responses should be tolerant, open-minded, courteous and tactful. Particular care should be exercised to avoid inhibitions	6, 10, 12, 15, 18, 19
Questions should, whenever possible, demand the use of facts in their relationships, i.e., demand organization of thought	2, 6, 8, 12

The student appraisal of student teacher questionnaire was administered to the pilot study students during the class period following the presentation of the treatment lesson. The documented DEST 02 program, from the Division of Educational Research Services at the University of Alberta, was used to determine a Cronbach α coefficient of reliability.

During computer analysis, the student responses for the five negative format statements were corrected for direction. The Cronbach α determination of reliability, and the correlation between the negative format and the positive format statements were low. It was hypothesized that in responding to the appraisal form, students may have misread or misinterpreted the negative format statements. Thus, further Cronbach α determinations were done on only the responses to the positive format statements. The resulting Cronbach α determinations for each category and for both treatment groups summarized in table XV indicate that the resultant appraisal form is a reliable instrument.

TABLE XV

PILOT STUDY CRONBACH α'S FOR STUDENT APPRAISAL FORM

Statements No.	Topic	Student Treatment Groups	Cronbach Alpha
12	Student teacher teaching effectiveness	1	0.88
12	Student teacher teaching effectiveness	2	0.86
7	Student teacher questioning effectiveness	1	0.84
7	Student teacher questioning effectiveness	2	0.87

The revised student appraisal of student teacher questionnaire, (see appendix H) was administered to the research study students in the class period following the presentation of the treatment lesson. The student responses to this administration were submitted to the DEST 02 program from the Division of Educational Research Services at the University of Alberta and the Cronbach coefficient of reliability was determined to be 0.87. Thus, the reliability of the instrument was confirmed during the research study.

Data Collection

The NCS General Purpose Trans-optic F4521 answer sheet was used for recording student responses to all instrument items. Each answer sheet was coded for student, student teacher, lesson taught and wait-time used. Fifteen answer sheets from each treatment group were randomly selected for subsequent analyses and machine scored.

Development and Description of Procedures Associated With Treatments

A major prerequisite to this research was the development and refinement of various techniques and procedures associated with the presentation of the treatments and the collecting and handling of data associated with those treatments. These topics, discussed in detail in subsequent sections of this chapter, are as follows:

A. Use of Blosser's Question Category System for Science, (Blosser, 1973);

B. Development of the instructional unit on science, society and technology for use in the treatment lessons;

C. Development and use of a question asking strategy to assist the student teachers in controlling their wait-time;

D. Measurement of student teacher higher cognitive level question wait-times; and,

E. Student teacher achievement of specified wait-time ranges for higher cognitive level questions.

A. Use of Blosser's Question Category System for Science (QCSS)

The Question Category System for Science (QCSS), developed and described by Blosser (1973), was selected for use in this study in preference to various other question category systems described in the literature. The decision to use this system was mainly based on the fact that the QCSS was specifically developed for use in science classrooms and for categorizing science related questions. Further, this system is quite appropriate for this study since the second level categories (summarized in table XVI), allow for the separation of lower cognitive level questions (cognitive memory questions) from higher cognitive level questions, (convergent thinking, divergent thinking and evaluative thinking questions) -- the separation of questions that would be required by the student teachers during the presentation of the treatment lessons. It was not necessary for them to distinquish among the last three categories of level II since such questions would require the same extended question wait-times during the treatment lessons.

TABLE XVI

SUMMARY OF THE QCSS LEVEL II QUESTION CATEGORIES

Category	Description of Questions
Cognitive Memory Questions	Require the simple reproduction of facts, formulas and other items of remembered content through the use of such processes as recognition, rote memory and selective recall.
Convergent Thinking Questions	Involve analysis and integration of given or remembered data. Are designed to stimulate translation, association, explanation and drawing conclusions.
Divergent Thinking Questions	Respondents are free to generate their own data within a "data-poor" situation. Are designed to stimulate elaborations, divergent association, implications or syntheses.
Evaluative Thinking Questions	Deal with matters of value rather than matters of fact. Contain the implication that the respondent may be called upon to justify his answer

Science educators from the Department of Secondary Education at the University of Alberta were involved in determining the proportions of agreement that could be expected among coders in classifying science questions as to either low cognitive level (cognitive memory questions of the QCSS) or high cognitive level (convergent thinking, divergent thinking or evaluative thinking questions of the QCSS). A total of thirty questions were prepared by the researcher with the aid of Blosser's Handbook of Effective

Questioning Techniques as a source of categorized questions, and as a guide for their preparation, (see appendix I). Ten questions were low cognitive level (Cognitive Memory) and twenty questions were high cognitive level questions (Convergent Thinking, Divergent Thinking and Evaluative Thinking). Two science teacher educators and three science education graduate students were provided with the QCSS and descriptions of each category of questions in level II of the system, and requested to categorize each of the 30 questions. These science educators achieved extremely high proportion of agreement levels. They were in total agreement in the classification of all low cognitive level questions and with regard to the high cognitive level questions, one science educator wrongly classified a convergent thinking question as a cognitive memory question. Thus, from this investigation, it was concluded that the QCSS was easily learned, and that a high proportion of agreement can be expected between categorizers who do not have extensive training or practice in the use of the system.

Training student teachers in the use of the QCSS for categorizing questions during the pilot study was as follows:

1. The student teachers familiarized themselves with the QCSS as developed by Blosser, 1973 (see appendix J).

2. They studied examples of questions (see appendix K) for each category of level II of the QCSS which had been developed by the author (Blosser, 1973).
3. They prepared questions, classified them to the categories of level II of the QCSS, and discussed their classifications with their peers; and,
4. They practiced the categorization of questions according to level II categories of the QCSS during student teaching at the junior high school (Ed. Pr. 355).

The pilot study student teachers' abilities in classifying science questions were determined in association with their student teaching experiences in the junior high schools (Ed. Pr. 355). During Ed. Pr. 355, each pilot study student teacher prepared and taught a lesson of approximately 30 minutes in duration with an emphasis on the use of questions. They audiotaped their lessons and transcribed all cognitive questions that were asked during the lesson. Copies of the transcribed questions were independently classified as to either low cognitive level or high cognitive level, as defined, by the student teacher who taught the lesson, and by the researcher. The proportion of agreement between each pilot study student teacher and the researcher was determined according to the following formula:

$$\frac{\text{Questions congruently classified by student teacher and researcher as to either low or high cognitive level}}{\text{Total number of cognitive questions asked}} = \text{Proportion of Agreement}$$

The proportion of agreement, which was greater than 0.81 for each of the four pairs, provided further evidence in support of the conclusion that the QCSS is easily learned, and high levels of agreement can be expected between coders when they use it to distinquish low cognitive level questions (cognitive memory recall questions) from high cognitive level questions (convergent thinking, divergent thinking or evaluative thinking questions).

Following their round of student teaching at the junior high schools (Ed.Pr. 355), the pilot study student teachers discussed their experiences in using the QCSS with the researcher, and provided suggestions for improving the training for its use. The suggestions were as follows:

1. The amount of practice in writing and classifying questions during the method courses (Ed. C.I. 370 and Ed. C.I. 371) should be increased; and,
2. The classification of questions with the QCSS should be practiced during peer teaching sessions in Ed. Pr. 354 prior to student teaching in the junior high schools (Ed. Pr. 355).

In response to the pilot study student teacher suggestions, and the pilot study findings, training in the use the QCSS for the research study was as follows:

1. During Ed. C.I. 370, student teachers familiarized themselves with the system through studying the QCSS (see appendix J), and examples of questions for each category of level II in the system (see appendix K).
2. Each student teacher prepared ten questions related to the teaching of a science concept, classified them at the level II categories of the QCSS and discussed such classifications with other class members.
3. Each student teacher independently categorized a total of 42 prepared questions relating to various concepts in science to level II categories of the QCSS. The source of the prepared questions and keyed answers was the Handbook of Effective Questioning Techniques (Blosser, 1973).
4. In the second and fourth peer teaching sessions (Ed. Pr. 354) during the second and ninth weeks of the term, each student teacher presented a science concept through the use of prepared questions which they classified to be either low cognitive or high cognitive level, as defined. Student teachers worked in pairs in classifying the questions and reached agreement levels of at least 0.90.

A final determination of the research study student teachers' abilities to categorize low cognitive level and high congitive level questions according to level II categories of the QCSS was performed during the week immediately prior to Ed. Pr. 356, the round of student teaching during which the research study treatments were given. The thirty questions (see appendix I) that had been categorized by science teacher educators and science education graduate students at the University of Alberta, were categorized by each student teacher. The summary of their percent success levels in categorizing questions is presented in table XVII.

TABLE XVII

RESEARCH STUDY STUDENT TEACHER SUCCESS LEVELS IN CATEGORIZING QUESTIONS ACCORDING TO THE Q.C.S.S.

Student Teacher Code Number	Percent Success In Identifying Low Cognitive Level Questions	Percent Success In Categorizing Convergent, Divergent or Evaluative Thinking Questions	Percent Success In Distinquishing Low From High Cognitive Level Questions
01	90	80	93
02	100	80	97
03	100	80	97
04*			
05	100	60	87
06	90	55	90
07*			
08	100	65	93
09	90	80	97
10	100	60	87
11	90	70	97
12	90	75	93
13	80	45	80
14	90	60	87
15	100	70	100
16	90	50	93
17	100	60	90

* Student teachers 04 and 07 withdrew from the teacher education program.

The results reported in table XVII indicate that the student teachers in this study had some difficulty in distinquishing among convergent, divergent and evaluative thinking questions and were highly successful in distinguishing low cognitive level questions from high cognitive level questions. Since this study requires that the student teachers control their question wait-time ranges with all higher cognitive levels, and do not have to distinquish among convergent, divergent and evaluative thinking questions, the QCSS was judged to be a satisfactory question classification system for use in this study.

The procedure for categorizing the questions asked by the student teachers during the treatment lessons was as follows:

1. Immediately following the presentation and audio-taping of each lesson to the treatment groups, each student teacher transcribed the questions asked;
2. Copies of the transcribed questions were independently categorized as to either low or high cognitive levels by the student teacher, a secondary science education graduate student with four years of science teaching experience at the secondary school levels and the researcher;
3. When incongruencies in the categorization of questions occurred, the three categorizers met to discuss such incongruencies and reach agreement in the categorizations; and,
4. Agreement was achieved mainly through the considerations of the level of the student response. When the student responded with a non-answer or when the student response was not audible, the categorization of the question was based on the

student teacher's intent of the question.

A sampling of the questions asked and the categorization of those questions is presented in appendix L.

B. Development of the Instructional Unit on Science, Society and Technology for Use in the Treatment Lessons

An instructional unit on the interrelationships of science, society and technology was developed for use in the presentation of the treatment lessons, and refined as a result of experiences during its use in the pilot study. Development of the unit by science education student teachers was based on chapter one of Science Past-Science Future, (Asimov, 1975) entitled, "Technology and The Rise of Man", and a publication on scientific literacy, (Evans, 1970). Initially, five instructional units which included questions and discussion topics were drafted.

After reading the reference materials and studying the five drafts, the pilot study student teachers selected a preferred draft and provided suggestions for its improvement. A revised draft, which accomodated the concerns and suggestions for improvement, was prepared by the researcher for use in the pilot study treatment lessons (see appendix M).

Each of the four pilot study student teachers used the protocol materials in planning and presenting the treatment lessons which were audiotaped, and observed by his/her cooperating teacher. The cooperating teachers, with references to all treatment lessons, indicated that the instruction related to all behavioral objectives included in the instructional unit outline. The researcher analyzed the audiotape recording of each class and confirmed the cooperating teachers' observations.

Following the presentation of the treatment lessons, the pilot study student teachers met with the researcher and discussed their perceptions associated with the use of the instructional unit. They agreed that the class discussions during the treatment lessons frequently related to more than one instructional unit behavioral objective, simultaneously. Further, they reported that it was difficult to maintain a concentration on all of the objectives and the particular question wait-time range throughout the class discussions.

Finally, they indicated that the discussions and questioning during the treatment lessons did not always follow the sequence of questioning suggested in the instructional unit outline. As a result of their experiences, they recommended that the outline should be revised, as follows:

1. The number of main concepts should be reduced;
2. The number and specificity of behavioral objectives should be reduced; and,
3. Specific topic areas for discussion should not be identified as they can be developed according

to the interests and knowledge of the instructors during lesson preparations and presentations.

The instructional unit on the interrelationships of science, society and technology which was revised in response to the pilot study student teacher experiences is presented in appendix N.

The revised instructional unit outline was used by the research study student teachers in the preparation of their treatment lessons, as follows:

1. They studied the revised instructional unit outline, and the examples presented in "Technology and The Rise of Man", (Asimov, 1975) in relation to the development of concepts of the interrelationships of science, society and technology, during a two-hour seminar;
2. They analyzed other examples and topics, which became apparent during the seminar, in terms of their appropriateness for similar concept development at the grade XI level; and,
3. Each student teacher used the revised unit outline during the preparation of questions related to independently selected topic areas, and incorporated them into their treatment lesson plans.

Each student teacher presented their treatment lesson plan to each of two treatment groups (grade XI biology 20 classes) over a 60 minute interval for each group, during the third week of the Ed. Pr. 356 student teaching experiences.

C. <u>Development and Use of a Question Asking Strategy</u>

During the first round of student teaching (Ed. Pr. 355) at junior high schools, the pilot study student teachers attempted to achieve specific wait-time ranges. They had some difficulty with the students calling out answers to recall questions which tended to persist with higher level questions. They attempted to practice the technique of ask a question - pause - call a student's name. Their wait-time range success levels were still low, because students continued in calling out answers.

If student teachers are to achieve particular question wait-time ranges, they must use question asking strategies that will assist them in controlling the wait-times. The following suggestions were given to the pilot study student teachers prior to their placements in the schools for Ed. Pr. 356 (with treatment groups):

1. Let the pupils become aware of your strategy. It was suggested that the student teachers tell their students that they will be asking questions and giving everyone some time to think before calling on someone to give an answer, and that all students should try to use the time for thought.

Further, the students should not interrupt each other's thoughts by speaking out or calling out answers.

2. Have a lesson prepared in advance, which will allow you and the class, to immediately use the technique for the most part of the class period.
3. If necessary, keep reminding students in the class of your technique as some may persist in calling out answers.
4. Use the tape recorder to check your use of the technique.
5. Plan your questions in advance of the lesson for as many high level questions as possible.
6. In planning your questions, phrase them precisely. (Sixteen examples of skeletal questions or formats of higher cognitive level questions were given to the student teachers.
7. Do not fall into the habit of verbally revising a question two or three times as you ask it, throwing not one but two or three questions at the students. Revising questions several times confuses students.
8. Avoid directing a majority of the questions to the class volunteers. Use a mixture of both groups of students.
9. Avoid asking questions requiring a "yes" or "no"

answer unless it is to be followed by a thinking question or is used during probes or prompts.

The technique of ask a question - pause - call a student's name was practiced by each pilot study student teacher with each treatment group two times in advance of their teaching the unit on science, society and technology.

The student teachers reported that when the technique was explained and the students were aware as to the reason for the pause, they were most cooperative. They also reported that the technique was most helpful in assisting them control their wait-time ranges during the treatment lessons.

Analysis of the audiotapes from the treatment lessons confirmed that the pilot study student teachers were quite successful in following this question asking strategy and in gaining the cooperation of their students.

Student teachers in the main study similarly practiced the question asking strategy in both the junior high school and senior high school classes prior to their teaching of the treatment lessons. They informed their treatment groups of the question asking strategy and that they would be following that strategy in order to allow everyone in class some time to think prior to calling on someone for an answer. They did not indicate that a particular treatment group (class) would have more or less time than another treatment group.

D. Measurement of Student Teacher Question Wait-Times

The wait-time measured was the time interval which began when the teacher stopped speaking after asking a question and terminated when the teacher called upon a student for a response, a student began a response or the teacher began to speak again.

A Moseley Strip Chart Recorder was used to obtain a graphic representation of the verbalizations and pauses that occurred during the lessons directly from the lesson audiotapes. The graph paper movement through the recorder was set at the slowest rate or one unit per 0.75 seconds which allowed for direct and accurate measurements of pauses or wait-times.

The procedure for measuring the higher cognitive level question wait-times using the strip chart recorder was established as follows:

1. The questions asked by the student teachers during the treatment lessons were transcribed from the audiotape, numbered and categorized as either low or high cognitive level.
2. The researcher coded the charts for the verbal interactions as the audiotape was played through the strip chart recorder. See figures 2 and 3 for duplications of coded strip chart records of verbal interactions produced from audiotapes

recorded during 1-4 and 4-7 second wait-time treatment presentations, respectively.

3. The wait-times for the higher cognitive level questions were subsequently determined from linear measurements of the strip chart recordings.

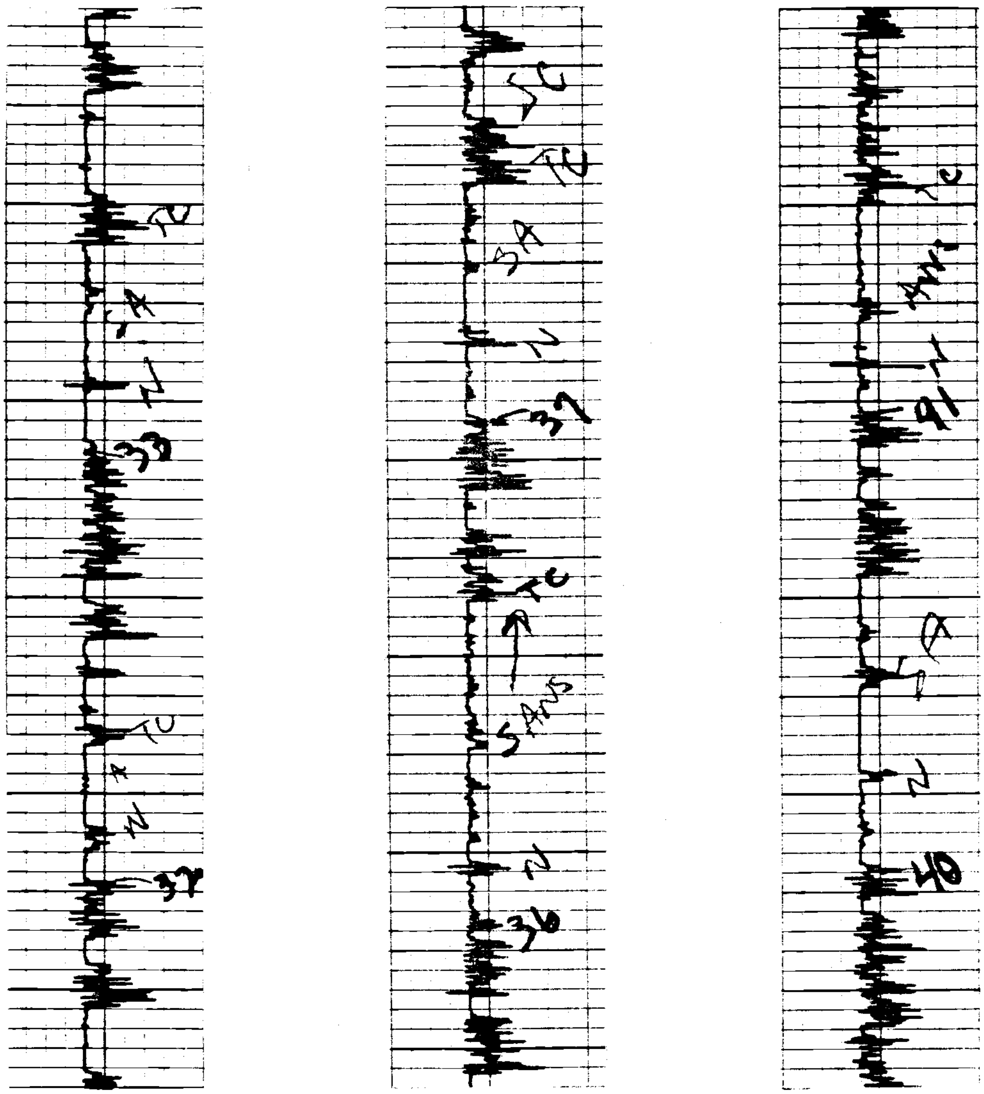

Figure 2. Coded strip chart records of question interactions from 1-4 second wait-time treatment groups. The numbers indicate the end of particular questions asked by the student teachers during the treatment lesson presentations. N represents the naming of a student, A, SA and ANS represent the beginning of a student's response, TC codes for a student teacher comment and SC codes for a student comment.

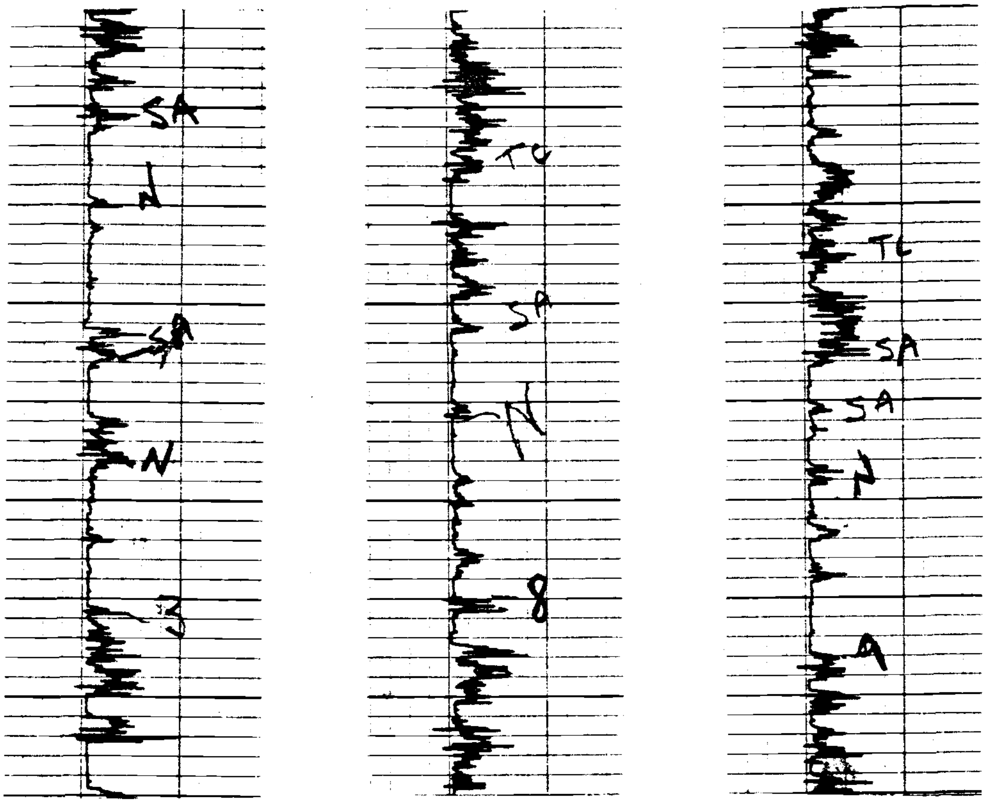

Figure 3. Coded strip chart records of question interactions from 4-7 second wait-time treatment groups. The numbers indicate the end of particular questions asked by the student teachers during the treatment lesson presentations. N represents the naming of a student, A, SA and ANS represent the beginning of a student's response, TC codes for a student teacher comment and SC codes for a student comment.

Figures 2 and 3 show some movements of the tracing needle at times other than when someone was speaking. Such movements resulted from three main problems associated with the taping of the lessons. Firstly, the movements of the student teachers during lessons found them at varying distances from the stationery microphones used. Secondly, the lessons were taught in regular classrooms which have limited acoustical qualities. Finally, regular classroom background noises were picked up by the microphone.

The accuracy of measuring wait-times from strip chart records was compared with the accuracy of measuring wait-times with a stop watch. The wait-times for ten randomly selected questions were determined with the use of a stop watch with a 0.1 second unit of measurement and from the linear measurement of a strip chart recording. The wait-times for each question as measured by the two methods were consistently within 0.1 second. Thus, the accuracy in measuring wait-times from strip chart recordings was confirmed as an acceptable method for measuring wait-times.

E. Student Teacher Achievement of Specified Wait-Time Ranges for Higher Cognitive Level Questions

The pilot student student teacher success level in achieving the specified higher cognitive level question wait-time ranges was determined as follows:

$$\frac{\text{Number of high cognitive level questions asked using the specified wait-time range}}{\text{Total number of high cognitive level questions asked}} \times 100 = \%\ \text{success}$$

During practice lessons with junior high school classes, the pilot study student teachers achieved success levels of 70-80% with the 1-4 second wait-time range classes and 45-85% with the 4-7 second wait-time range classes. The lower levels of success occurred in those classes where the student teacher did not establish a routine or explain to the students the technique that would be followed when questions requiring some thought were asked. In these situations, the students usually called out answers in advance of the specified wait-time range. Such experiences established the need for setting and explaining a question asking strategy to the students. As discussed in the previous section, suggestions for explaining, establishing and using a question asking strategy to assist student teachers in achieving specific higher cognitive level question wait-time ranges were prepared. Those suggestions were incorporated into the pilot study prior to the presentation of treatment lessons.

The analysis of the tapes from the pilot study treatment lessons with the strip chart recorder indicated high success levels for achieving the specified wait-time ranges. When the student teachers taught the unit using the 1-4 second higher cognitive level question wait-time range, their success levels ranged from 80-95%. With the 4-7 second higher cognitive level question wait-time range treatment groups, the student teachers achieved success levels ranging from 73 to 83%.

Further detailed analyses of the tape recordings and strip charts provided the following information:

1. When the question wait-times for the short wait-time range classes were not achieved, it was primarily because the student teacher waited too long before calling a student's name; and,
2. When the question wait-times for the longer

wait-time range classes were not achieved, it was usually because the student teacher did not wait long enough.

As a result of the pilot study findings, it was decided that only the student data from those classes where the student teacher achieved the criterion wait-time ranges with at least 70% of the higher cognitive level questions would be used in the main study. This requirement and the experimental mortality of student teachers had a direct effect on limiting the amount of data that could be used in the statistical analyses associated with this research, as follows:

1. Two of the seventeen student teachers in the class withdrew from the teacher education program prior to the round of student teaching in which the treatments were given;
2. Three student teachers experienced technical difficulties with the audiotaping of their treatments with at least one of their lessons; and,
3. Four student teachers did not achieve a 70 percent higher cognitive level question wait-time success level with their 4-7 second wait-time range treatment groups.

Thus, of the seventeen student teachers who were initially involved in this research, eight were successful in achieving the criterion wait-time range with each treatment group. Their success levels with each treatment group are summarized in table XVIII.

TABLE XVIII

STUDENT TEACHER SUCCESS LEVELS IN ACHIEVING SPECIFIC HIGHER COGNITIVE LEVEL QUESTION WAIT-TIME RANGES

Student Teacher (Code No.)	Student Teacher Group	Total Higher Cognitive Level Questions Asked		Percent Success	
		1-4 second wait-time class	4-7 second wait-time class	1-4 second wait-time class	4-7 second wait-time class
01	1	36	22	88.9	86.4
02	2	67	46	71.6	84.8
05	2	56	28	88.6	75.6
11	1	68	85	86.7	74.1
12	2	44	41	87.7	80.5
14	2	49	59	83.9	81.5
15	1	84	86	83.3	72.1
17	1	34	35	81.2	78.6

As expected, the student teachers experienced greater difficulty in achieving the longer 4-7 second wait-time range than they did in achieving the 1-4 second wait-time range. Only one of these student teachers had a lower than 80 percent success level with the shorter 1-4 second wait-time range treatment group. In this case, the tape recording indicated that the question wait-times which did not fall within the 1-4 second range were slightly longer than four seconds. Three student teachers had success levels of less than 80 percent with the longer 4-7 second wait-time range. The tape recordings from these treatment groups indicated that the question wait-times which did not satisfy the 4-7 second wait-time range were usually less than 4 seconds.

The tape recordings of the four student teachers who did not achieve a 70 percent success level with their 4-7 second wait-time treatment groups indicated that they did not adequately practice a question asking strategy that would help them control their wait-times. In these cases, some students tended to call out answers before anyone was called upon by the student teacher during the treatments. Occassionally, these student teachers identified a particular student as the respondent to a particular question before they asked it. This practice allowed the identified respondent to answer the question whenever ready which was usually in less than 4 seconds after the question was asked. It is also likely that many of the other students in the class did not concern themselves with thinking of an answer to the question asked. Thus the effect of the question in stimulating thought would be lost.

Of the eight student teachers who were successful in achieving the criterion wait-time ranges with at least 70 percent of the higher cognitive questions asked, four taught the 1-4 second wait-time treatment group first, and the other four taught the 4-7 second wait-time treatment group first.

The Finalized Design Matrix

The finalized design matrix presented in figure 4 identifies specific sample sizes that are based on the actual number of student teachers who were successful in achieving the criterion wait-time ranges in each treatment group for at least 70 percent of the higher cognitive level questions asked.

Students	Pretest	Treatment	Achievement Test and Appraisal Scale
Treatment I (1-4 second wait-time range)	40 item biology achievement test	Taught by Group 1 student teachers	N = 60
		Taught by Group 2 student teachers	N = 60
Treatment 2 (4-7 second wait-time range)		Taught by Group 1 student teachers	N = 60
		Taught by Group 2 student teachers	N = 60

Figure 4. Finalized design matrix. Group 1 student teachers taught the treatment lesson using the 1-4 second higher cognitive level question wait-time range to one class before using the 4-7 second higher cognitive level question wait-time range with a second class. Group 2 student teachers used the reverse order of treatment lesson presentations.

The sample size of 60 permitted a $1 - \beta = .75$, where $\gamma = 0.25$ and $\alpha = .05$ (Cohen, 1969, p. 377).

This power level assures that Type II errors would not be made more than 25 percent of the time in the testing of the hypotheses.

Statistical Analyses

The ANCV 15 program of the Division of Educational Research Services (DERS) library at the University of Alberta was selected to complete a one-way analysis of covariance on the data related to the testing of hypothesis 1. The covariate measure was the achievement test on the cognitive objectives of the biology program which the students had completed during their previous year of study. The criterion measure was the achievement test on the cognitive objectives of the instructional unit presented during the treatments.

The Mulv 08 program of the DERS library at the University of Alberta was selected to complete the two-sample Hotelling T^2 test to determine whether students perceive student teachers who use a 4-7 second higher cognitive level question wait-time range as being either more or less effective than student teachers who use a 1-4 second higher cognitive level question wait-time range.

Summary

This chapter has described the choice of the research design and the research methodology. The samples of students, student teachers and cooperating teachers, and their involvements in the pilot and research studies have also been described.

Details of the development and refinement of data gathering instruments, which included a covariate achievement test, an achievement posttest aimed at determining student achievement of objectives in the instructional unit taught by the student teachers during treatment lessons, and a student appraisal of student teacher effectiveness questionnaire were presented.

The development and revision of an instructional unit on science, society and technology, used by the student teachers in the preparation and presentation of treatment lessons, were outlined in detail.

The question asking strategy used by the student teachers, during treatment lessons, as an aid to achieving specific higher cognitive level question wait-time ranges was outlined in detail. The method for measuring student teacher higher cognitive level question wait-times was summarized and the success levels of student teachers in achieving specific wait-time ranges were reported.

Finally, the design matrix was presented, and the methods for statistical analysis of the experimental data was outlined.

CHAPTER IV

THE RESULTS

This chapter presents the results of the research which is organized into four major sections. The first section presents data pertaining to the testing of hypothesis 1 and the second section presents further analysis of the data associated with hypothesis 1. The third section deals with the testing of hypothesis 2 and the fourth section presents some further analyses of data relating to hypothesis 2.

Research Hypothesis 1

Hypothesis 1 is as follows:

H_1: There is no significant difference ($\alpha = 0.05$) between the mean achievement level of grade XI biology students taught by biology student teachers using a 1-4 second higher cognitive level question wait-time range and the mean achievement level of students taught by the same student teachers using a 4-7 second higher cognitive level question wait-time range.

The documented ANCV 15 program of the Division of Educational Research Services (DERS) at the University of Alberta, Edmonton, Alberta, was used to carry out a one-way analysis of covariance to test hypothesis 1. The covariate measure was the achievement test of the cognitive objectives of the biology 10 program which the students had completed during their previous year of study. The criterion measure was the achievement test of the cognitive objectives of the instructional unit on science, society and technology presented during the treatments.

The test statistics of the covariate and criterion measures for the two groups in the study are summarized in table XIX.

TABLE XIX

TEST STATISTICS FOR COVARIATE AND CRITERION MEASURES

Treatment	N	Covariate Test Mean	Covariate Test S.D.	Criterion Test Mean	Criterion Test S.D.	Adjusted Criterion Test Mean
1	120	22.42	4.81	22.47	3.71	13.896
2	120	23.04	5.29	24.77	4.09	15.969

An examination of table XIX indicates that the criterion test score means were adjusted down for both treatment groups. The ANCV 15 program used in this analysis determines the adjusted criterion test score means, as follows:

$$\overline{Y}_{ad,j} = \overline{Y}_j - b(\overline{X}_j - X_o)$$

where:

$\overline{Y}_{ad,j}$ = adjusted criterion test mean(y-intercept)

$\overline{Y}_j$ = criterion test mean for sample j.

b = regression estimate for effect of covariate determined to be 0.382.

$\overline{X}_j$ = covariate test mean for sample j.

X_o = zero.

Table XX presents a summary of the one-way analysis of covariance (ANCV 15) program which tests hypothesis H_1.

TABLE XX

ANALYSIS OF COVARIANCE, TEST FOR HOMOGENEITY OF GROUP VARIANCE AND TEST FOR HOMOGENEITY OF REGRESSION

Source of Variation	S.S.	Df	MS	F	P
Wait-time	256.829	1	256.829	20.821	<.001
Cov.1	923.159	1	923.159	74.840	<.001
Errors	2923.437	237	12.335		

Bartlett Test for Homogeneity of Group Variance

$Df = 1 \quad X^2 = 1.217$
$P = 0.270$

Test for Homogeneity of Regression Coefficient

$F_{(1,236)} = 1.43$
$P = 0.231$

An examination of table XX reveals that the F-ratio for the covariate had a high level of significance indicating that the regression coefficient was not zero, and an adjustment was being made to the group means. The ANCV 15 program removes that part of the variability in student to student scores on the criterion test that can be accounted for by their variability on the covariate test in advance of the calculation of the F-ratio for the treatment effects. The difference between the two adjusted treatment group means of 2.073(see table XIX), has a highly significant F-ratio ($P<0.001$) as reported in table XX. Therefore hypothesis H_1 is rejected. The analyses indicate that the grade XI biology students who were taught by biology student teachers using a 4-7 second higher cognitive level question wait-time range achieved significantly higher than the grade XI biology students who were taught by the same biology student teachers using a 1-4 second higher cognitive level question wait-time range.

Further Analyses Related to Research Hypothesis 1

The results of the analysis of covariance summarized in the previous section indicated that treatment group 2 students achieved significantly higher results on a cognitive achievement test than treatment group 1 students who were taught the same instructional unit by the same student teachers. Half of the student teachers taught the instructional unit to treatment group 2 students first while the rest of the student teachers taught the unit to treatment group 2 students after teaching it to treatment group 1 students. The results of the analysis of covariance in this design raise the question as to whether there was interaction between student teacher familiarity with the instructional unit and higher cognitive level question wait-time range.

In order to answer this question of possible interaction, the student results from the covariate measure and the instructional unit achievement test were submitted to a two-way analysis of covariance. The factors input were student teacher question wait-time range and level of familiarity with the unit taught. The ANCV 25 program of the Division of Educational Research Services at the University of Alberta was used to carry out the two-way analysis of covariance.

The test statistics of the covariate and criterion measures for the four groups are summarized in table XXI.

TABLE XXI

TEST STATISTICS FOR COVARIATE AND CRITERION MEASURES (FOUR GROUPS)

Student Teacher Group*	N	Treatment**	Covariate Test Mean	Covariate Test S.D.	Criterion Test Mean	Criterion Test S.D.	Adjusted Criterion Test Mean
1	60	1	21.93	4.49	23.10	3.15	14.78
2	60	1	22.92	5.13	21.83	4.26	13.14
1	60	2	21.95	5.14	23.85	3.81	15.53
2	60	2	24.13	5.43	25.70	4.37	16.55

* Student Teacher Group 1: Taught instructional unit using 1-4 second higher cognitive level question wait-time range to first class and 4-7 second higher cognitive level question wait-time range with second class.

Student Teacher Group 2: Taught instructional unit with a 4-7 second higher cognitive level question wait-time range to first class and 1-4 second higher cognitive level question wait-time range with second class.

** Treatment 1: 1-4 second higher cognitive level question wait-time range.

Treatment 2: 4-7 second higher cognitive level question wait-time range.

The ANCV 25 program used in this analysis determines the adjusted criterion test means presented in table XXI, as follows:

$$\overline{Y}_{adj} = \overline{Y}_j - b(\overline{X}_j - X_o)$$

where:

$\overline{Y}_{adj}$ = adjusted criterion test mean(y-intercept)

$\overline{Y}_j$ = criterion test mean for group j.

b = regression estimate for effect of covariate determined to be 0.379.

$\overline{X}_j$ = covariate test mean for group j.

X_o = zero.

The ANCV 25 program used in this analysis removes that part of the variability in student to student scores on the criterion test that can be accounted for by their variability on the covariate test in advance of the calculations of F for each factor and for interaction effects. The summary of the two-way analysis of covariance is presented in table XXII.

TABLE XXII

TWO WAY ANALYSIS OF COVARIANCE, TEST FOR HOMOGENEITY OF GROUP VARIANCE AND TEST FOR HOMOGENEITY OF REGRESSION

Source of Variation	SS	Df	MS	F	P
Lesson familiarity	105.889	1	105.889	8.836	.003
Wait-time	257.252	1	257.252	21.468	<.001
Interaction	5.585	1	5.585	0.466	.495
Covariate	884.247	1	884.247	73.790	<.001
Error	2816.063	235	11.983		

Bartlett Test for Homogeneity of Group Variance

$$Df = 3 \quad X^2 = 7.296$$
$$P = 0.063$$

Test for Homogeneity of Regression Coefficient

$$F_{(3,232)} = 0.407$$
$$P = 0.748$$

The information summarized in tables XXI and XXII extend the findings of the one-way analysis of covariance. These analyses indicate that the students who were taught through a questioning strategy by student teachers who taught the instructional unit for the second time had a significantly lower mean achievement level than students who were taught by the same student teachers teaching the instructional unit for the first time. This finding is somewhat surprising in that one would expect student teachers who were more familiar with an instructional unit to teach it more effectively and as a result, have their students better comprehend the material presented. Further, it would be expected that the students would then demonstrate higher achievement on an associated achievement test. Perhaps the student teachers in this study became overly familiar with the material presented and rushed over crucial content during their second presentation or were not as aware of student misconceptions during the second presentation as they were during the first.

On the basis of the statistical analyses summarized in table XXII and the graphic representation in figure 5, it is evident that there is no significant interaction between student teacher familiarity with the instructional unit and student teacher use of high cognitive level question wait-time ranges. This suggests that student teacher experience in teaching an instructional unit and student teacher use of high cognitive level question wait-time ranges act independently in their effects on student achievement.

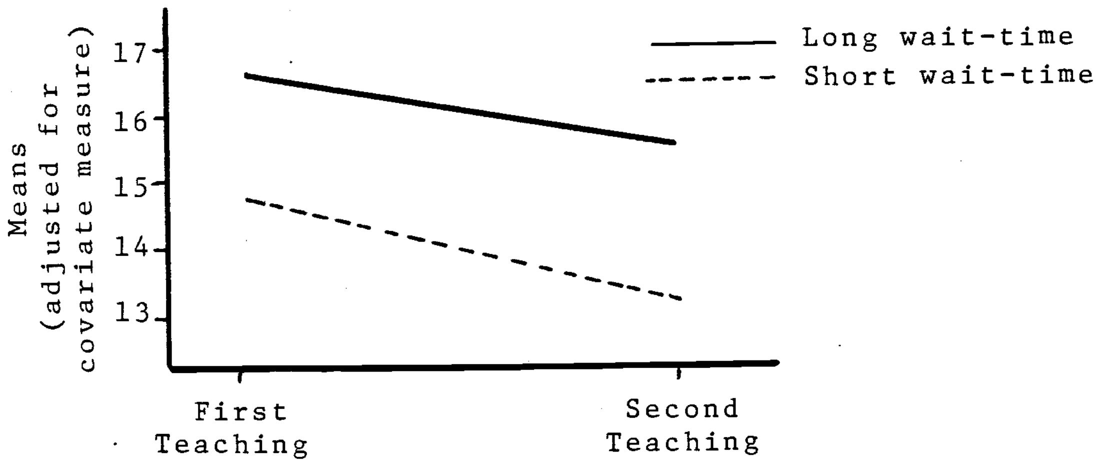

Figure 5. Wait-time X student teacher familiarity with lesson interaction for student achievement test on Science, Society, and Technology.

The covariate test, criterion test and adjusted criterion test means for each class sample were determined and are presented in table XXIII.

TABLE XXIII

COVARIATE, CRITERION AND ADJUSTED CRITERION TEST SCORE MEANS FOR EACH TREATMENT SAMPLE

Student Teacher Code No.	Student Teacher Group*	Treatment**	Covariate Test Mean	Criterion Test Mean	Adjusted Criterion Test Mean
01	1	1	20.7	22.2	23.0
		2	22.2	26.0	26.2
11	1	1	25.1	24.1	23.2
		2	22.3	22.9	23.1
15	1	1	19.9	23.5	24.6
		2	20.1	22.3	23.3
17	1	1	22.3	22.7	22.8
		2	22.7	24.2	24.2
02	2	1	23.6	21.3	21.0
		2	29.2	28.3	25.8
05	2	1	22.7	23.5	23.5
		2	22.5	25.3	25.4
12	2	1	21.6	20.1	20.5
		2	24.1	23.7	23.2
14	2	1	24.0	22.5	22.0
		2	20.7	25.5	26.3

* Student Teacher Group 1: Taught instructional unit using 1-4 second higher cognitive level question wait-time range to first class and 4-7 second higher cognitive level question wait-time range with second class.

Student Teacher Group 2: Taught instructional unit using 4-7 second higher cognitive level question wait time range to first class and a 1-4 second higher cognitive level question wait-time range with second class.

** Treatment 1: 1-4 second higher cognitive level question wait-time range.

Treatment 2: 4-7 second higher cognitive level question wait-time range.

The adjusted criterion test mean presented in Table XXIII is determined by:

$$\bar{Y}_{ad,j} = \bar{Y}_j + b(\bar{\bar{X}} - \bar{X}_j)$$

Where:

$\bar{Y}_{ad,j}$ = adjusted criterion test mean for sample j.

$\bar{Y}_j$ = criterion test mean for sample j.

b = regression estimate for effect of covariate determined by ANCV 25 program to be 0.379.

$\bar{\bar{X}}$ = overall covariate test mean.

$\bar{X}_j$ = covariate test mean for sample j.

A comparison of the adjusted criterion test means between treatment samples for each teacher, presented in table XXIII, reveals that the treatment 2 sample mean was higher than the treatment 1 sample mean for six of the eight student teachers (student teachers coded 01,02,05, 12, 14, and 17). The adjusted criterion test means for the two treatment classes taught by student teacher number 11 were very similar. Only one student teacher (number 15) taught treatment classes where the treatment 1 class had a higher adjusted criterion test mean.

Finally, the data were analyzed by analysis of variance in which the individual classes were identified as the experimental units. This analysis confirmed the findings from the analysis of covariance for the main treatment effect with an F-ratio of 8.088 ($F_{crit.}$ α =0.05, Df=1,6; is 5.99). The analysis of variance for familiarity effect had an

F-ratio of 5.12 (F_{crit} =5.99), and did not support the findings of the analysis of covariance. This analysis confirmed the absence of interaction between lesson familiarity and treatment with an F-ratio of 0.129 (F_{crit} = 5.99).

Research Hypothesis 2

Hypothesis 2 is as follows:

H_2: There is no significant difference ($\alpha = 0.05$) in students' perceptions of the effectiveness of biology student teachers who use a 1-4 second high cognitive level question wait-time range when compared to students' perceptions of the effectiveness of biology student teachers who use a 4-7 second high cognitive level question wait-time range.

The documented MULV 08 program of the Division of Educational Research Services (DERS) at the University of Alberta was used to carry out the Hotelling's T^2 to test hypothesis 2. The student responses on the 19 items pertaining to student teacher effectiveness from the Student Appraisal of Student Teacher questionnaire was the data used in the analysis. The Cronbach α Coefficient of reliability for the questionnaire was determined to be 0.87 which indicates that the instrument has a relatively high level of reliability.

The summary of the student responses to the questionnaire is presented in table XXIV.

TABLE XXIV

MEANS OF ITEMS OF STUDENT APPRAISAL OF STUDENT TEACHER QUESTIONNAIRE FOR TREATMENT GROUPS 1 and 2

Item		Taught with 1-4 second wait-time (N = 60)	Taught with 4-7 second wait-time (N = 60)
101.	The student teacher seemed to be friendly	1.392	1.375
102.	The student teacher asked questions about things we already knew.	3.158	3.092
103.	I was interested in the lesson	2.633	2.558
104.	The student teacher asked questions that made me think	2.333	2.367
105.	The student teacher explained the lessons clearly.	2.017	2.067
106.	The student teacher enjoyed teaching our class	1.933	1.900
107.	The questions asked helped me learn.	2.408	2.417
108.	The student teacher listened carefully to our answers.	1.500	1.575
109.	The student teacher helped us reason out answers to difficult questions.	1.842	1.917
110.	The student teacher used our answers in the discussion.	1.900	1.900
111.	I was free to disagree with the student teacher.	2.075	1.683
112.	The student teacher gave everyone a chance to answer questions.	1.667	1.617

TABLE XXIV - continued

MEANS OF ITEMS OF STUDENT APPRAISAL OF STUDENT TEACHER QUESTIONNAIRE FOR TREATMENT GROUPS 1 and 2

	Item	Taught with 1-4 second wait-time (N = 60)	Taught with 4-7 second wait-time (N = 60)
113.	The student teacher clearly explained what was planned.	2.067	2.083
114.	The student teacher encouraged everyone to ask questions.	1.950	2.017
115.	The student teacher was enthusiastic.	1.892	1.733
116.	The student teacher made good use of class time.	1.667	2.000
117.	The test was fair	2.267	2.342
118.	The student teacher explained how he/she would use questions to teach this unit.	2.475	2.617
119.	The student teacher was well prepared for the lesson.	1.683	1.842
120.	I learned a lot during the lesson.	2.342	2.475
	Overall Mean (Item 117 excluded)	2.049	2.065

The similarities of the two treatment group means for each variable presented in table XXIV suggest that the students perceived their student teachers as being equally effective.

The summary of the Hotelling's T^2 analysis for testing hypothesis 2 is presented in table XXV.

TABLE XXV

HOTELLING'S T^2 FOR TEACHER EFFECTIVENESS AND QUESTIONING ITEMS BETWEEN TREATMENT GROUPS 1 AND 2

T^2	DF1	DF2	F	P
34.991	19	220	1.702	0.037

Results of the Hotelling's T^2 analysis reported in table XXV indicate that there is a significant difference between group 1 and group 2 student perceptions of student teacher effectiveness at the 0.05 level of significance. Therefore hypothesis 2 is rejected. Because confidence intervals were not determined, the instrument was treated as an interval scale and the overall treatment group means (Table XXIV) were used to compare the treatment groups perceptions of their student teachers effectiveness. This comparison indicates that student teachers who use a 4-7 second higher cognitive level question wait-time range are perceived as being less effective than student teachers who use a 1-4 second higher cognitive level question wait-time range.

Further Analyses Related to Research Hypothesis 2

As a result of the Hotelling's T^2 determination of significant difference between the treatment group student perceptions of their student teachers, it is of interest to determine the variables of the Student Appraisal of Student Teachers questionnaire which contributed most to producing the statistically significant Hotelling's T^2.

The two treatment group means for each of the 12 items of the questionnaire that pertain to student teacher teaching effectiveness are given in table XXVI.

TABLE XXVI

MEANS OF ITEMS PERTAINING TO STUDENT TEACHER TEACHING EFFECTIVENESS FOR TREATMENT GROUPS 1 and 2

	Item	Taught with 1-4 second wait-time (N = 120)	Taught with 4-7 second wait-time (N = 120)
101.	The student teacher seemed to be friendly	1.392	1.375
103.	I was interested in the lesson	2.633	2.558
105.	The student teacher explained the lesson clearly	2.017	2.067
106.	The student teacher enjoyed teaching our class.	1.933	1.900
108.	The student teacher listened carefully to our answers.	1.500	1.575
110.	The student teacher used our answers in the discussion	1.900	1.900
111.	I was free to disagree with the student teacher	2.075	1.683
113.	The student teacher clearly explained what was planned	2.067	2.083
115.	The student teacher was enthusiastic	1.892	1.733
116.	The student teacher made good use of class time	1.667	2.000
119.	The student teacher was well prepared for the lesson	1.683	1.842
120.	I learned a lot during the lesson	2.342	2.475
	Sum of means	23.101	23.191
	Overall means	1.925	1.933

It is evident from an inspection of the means in table XXVI that there were no major differences between the groups in their mean perceptions of their student teachers' teaching effectiveness. Item 111 and 116 indicate slight trends. The means to item 111 suggest that the students in the 4-7 second wait-time treatment group felt freer to disagree with their student teachers, and the mean response to item 116 suggests that the same students thought that their student teachers used the class time less efficiently. Overall, the similarities in the means for the two treatment groups indicate that the students perceived their student teachers as being equally effective in terms of the items pertaining to teaching effectiveness in this questionnaire regardless of the question wait-time range used.

The two treatment group means for each of the seven items of the questionnaire that pertain to student teacher effectiveness in questioning are given in table XXVII.

TABLE XXVII

MEANS OF ITEMS PERTAINING TO STUDENT TEACHER USE OF QUESTIONS FOR TREATMENT GROUPS 1 and 2

Item	Taught with 1-4 second wait-time (N = 120)	Taught with 4-7 second wait-time (N = 120)
102. The student teacher asked questions about things we already knew	3.158	3.092
104. The student teacher asked questions that made me think	2.333	2.367
107. The questions asked helped me learn	2.408	2.417
109. The student teacher helped us reason out answers to difficult questions	1.842	1.917
112. The student teacher gave everyone a chance to answer questions	1.667	1.617
114. The student teacher encouraged everyone to ask questions	1.950	2.017
118. The student teacher clearly explained how he/she would use questions to teach this unit	2.475	2.617
Sum of means	15.833	16.044
Overall mean	2.262	2.292

An inspection of the means reported in table XXVII indicates a similarity in the two treatment group student perceptions of their student teachers in terms of the items pertaining to the use of questions during the instruction of the treatment lessons. These similarities suggest that the student teachers were equally effective in using their questioning strategy with each treatment group.

The MULV 08 program from the Division of Educational Research Services at the University of Alberta was used to determine Hotelling's T^2's for the 12 teaching effectiveness items and the seven questioning effectiveness items. The summary of the Hotelling's T^2 for the 12 items on teaching effectiveness is presented in table XXVIII.

TABLE XXVIII

HOTELLING T^2 FOR STUDENT TEACHER TEACHING EFFECTIVENESS ITEMS BETWEEN TREATMENT GROUPS 1 AND 2

T^2	DF1	DF2	F	P
0.014	12	227	0.001	>.25

The results of the Hotelling's T^2 analysis summarized in table XXVIII indicates that there was no significant difference, at the 0.05 level, between the two treatment groups' perceptions of their student teacher's teaching effectiveness.

The Hotelling's T^2 for the seven items pertaining to the student teacher questioning effectiveness is presented in table XXIX.

TABLE XXIX

HOTELLING T^2 FOR STUDENT TEACHER QUESTIONING EFFECTIVENESS ITEMS BETWEEN TREATMENT GROUPS 1 AND 2

T^2	DF1	DF2	F	P
0.227	7	232	.031	$>.25$

The results of the Hotelling's T^2 analysis summarized in table XXIX indicate that the difference between the two treatment groups' perceptions of their student teachers' use of questioning was not significant.

Thus, neither the items for student teacher teaching effectiveness, nor the items for student teacher use of questions were critical in producing the significant Hotelling's T^2 reported in table XXV.

Finally, in this effort to determine those variables which contributed most to producing a significant difference between group 1 and group 2 student perceptions of their student teachers' effectiveness based on their responses to the statements of the instrument used, the Division of Educational Research Services MULV 02 program was used. The F-ratio and probability for each item are presented in table XXX, and each F-ratio determination is presented in detail in appendix O.

TABLE XXX

F-RATIOS AND PROBABILITIES OF THE TEACHING EFFECTIVENESS AND QUESTIONING EFFECTIVENESS ITEMS

Item	F-ratio	P
101	0.047	0.829
102	0.502	0.479
103	0.329	0.567
104	0.113	0.737
105	0.211	0.647
106	0.095	0.759
107	0.006	0.940
108	0.697	0.405
109	0.475	0.491
110	0.000	1.000
111	10.032	0.002
112	0.190	0.663
113	0.023	0.880
114	0.300	0.585
115	2.400	0.123
116	8.984	0.003
118	1.137	0.287
119	2.013	0.157
120	1.171	0.280

Only two of the F-ratios for the teaching effectiveness and questioning effectiveness items presented in table XXX indicate significant differences between the two treatment group means. These are for items 111 and 116 which have probability levels of 0.002 and 0.003, respectively. It would appear that the student responses for these two items would have a major influence in producing a significant difference between the 1-4 and 4-7 second wait-time treatment groups in their perceptions of their student teachers' effectiveness. However, when these findings are related to the item means for each group, presented in table XXIV, it is noted that the mean differences between the 1-4 second and 4-7 second wait-time treatment groups for these items are of opposite sign and thus not additive in their influence in producing a significant difference between the perceptions of the two treatment groups. Thus, these efforts toward determining those variables of the student appraisal of student teacher effectiveness questionnaire which contribute most toward producing a significant Hotelling T^2 have not been conclusive.

Summary

The chapter has presented the statistical analyses of the data which resulted with the rejecting of the two research hypotheses.

With reference to hypothesis 1, the analysis indicated that students who were taught a particular biology instructional unit by biology student teachers using a 4-7 second higher cognitive level question wait-time range achieved significantly higher than students who were taught the same instructional unit by the same student teachers using a 1-4 second higher cognitive level question wait-time range ($P < 0.001$). Further analysis of the data indicated that students who were taught by student teachers teaching the unit for the second time achieved significantly lower than the students who were taught by the same student teachers teaching the unit for the first time. It also indicated that there was no significant interaction between student teacher higher cognitive level question wait-time range and familiarity with the instructional unit in producing the significant difference in student achievement between treatment groups.

With reference to hypothesis 2, the analyses indicated that students perceived biology student teachers who used a 4-7 second higher cognitive level question wait-time range as being less effective than student teachers who used a 1-4 second higher cognitive level question wait-time range ($P = 0.037$). Attempts to determine specific variables which contributed most in this determination of statistically significant difference were inconclusive.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents the summary, conclusions and recommendations, and is presented in three sections. The first section presents a summary of the research procedures, a summary of the results and a brief discussion of those results. The subsequent section presents a discussion of certain findings during the statistical analyses which restricted the extending of the results toward definitive conclusions. The final section summarizes the suggestions and recommendations for further research on teacher question wait-time respond to the findings of this study.

Summary of the Research Procedures

The study was designed to study possible relationships between biology student teacher higher cognitive level question wait-time range and grade XI (biology 20) student achievement, and to determine whether the students perceive student teachers who use a 1-4 second higher cognitive level question wait-time range as being more or less effective than student teachers who use a 4-7 second higher cognitive level question wait-time range. The treatments involved each student teacher in teaching a 60 minute unit of instruction on the interrelationships of science, society and technology to each of two treatment groups. Their familiarity with teaching the instructional unit was controlled between treatment groups by having half of the student teachers teach the instructional unit using the 1-4 second higher cognitive level question wait-time range first and the other student teachers teach the instructional unit using the 4-7 second higher cognitive level question wait-time range first.

The research procedures, and instruments were refined through a pilot study during the fall term, 1980. It was integrated with two campus based biology teacher education curriculum and instruction courses, one campus based practicum course, two school based practicum courses, and the grade XI (biology 20) Alberta curriculum. The research study took place over a period of 14 weeks.

The entire phase III biology teacher education class of 17 student teachers was initially involved in the study. In association with their teaching of the treatment lessons to the treatment groups, the student teachers were involved in various activities as follows:

1. Familiarization, training and practice in the use of Blosser's Question Category System for Science (Q.C.S.S.), Blosser, 1973;

2. Practice in the stating of recall and higher cognitive level questions where the higher cognitive level questions are defined as those which would be categorized as either convergent thinking, divergent thinking or evaluative thinking questions according to Blosser's Q.C.S.S.;
3. Practice in the use of a question asking strategy designed to facilitate the control of their higher cognitive level question wait-time ranges;
4. Self and peer appraisal in the effective use of the question asking strategy;
5. Development of the instructional unit used with the treatment groups; and,
6. Transcription and categorization of questions asked during the presentation of the instructional unit to the treatment groups.

The pilot study, which involved four selected biology education student teachers and eight biology 20 classes, was completed during the university term previous to the term in which the research study was done. It indicated that student teachers could control their higher cognitive level question wait-time ranges. The four student teachers in the pilot study were able to achieve the criterion wait-time ranges with at least 73% of the higher cognitive level questions asked of their treatment groups. A success level for achieving the criterion wait-time ranges was set at 70 percent for the study.

The research study student teacher sample consisted of an entire class of 17 biology student teachers who were in their final phase of the program. During the study, two student teachers withdrew from the biology teacher education program and eight of the remaining 15 were successful in achieving the criterion higher cognitive level question wait-time ranges with each treatment group for at least 70 percent of the higher cognitive level questions asked. Four of these student teachers taught their first treatment group using a 1-4 second higher cognitive level question wait-time range and four taught their first treatment group using a 4-7 second higher cognitive level question wait-time range. Thus, the cell sizes for the number of student teachers teaching each treatment group were equal.

The student sample consisted of grade XI (biology 20) students from Edmonton area senior high schools who were being taught by experienced biology teachers. These biology teachers were also cooperating teachers in the biology teacher education program at the University of Alberta. Two biology 20 classes from each cooperating teacher, or a total of 34 classes, were initially involved.

The tests and data gathering instruments were as follows:

1. An achievement test consisting of 40 objective

items aimed at assessing student achievement of the cognitive objectives for biology 10. It was administered to all treapment group students at the beginning of the school semester in which the study took place.

2. An achievement test consisting of 40 objective items aimed at assessing student achievement of the cognitive objectives of the instructional unit on science, society and technology. This test was administered during the class period following the presentation of the treatment lessons on science, society and technology to the treatment groups.

3. A 20 item questionnaire aimed at determining the student perceptions of their student teachers effectiveness in teaching which was administered immediately after the science, society and technology test.

The content validity of the biology 10 achievement test was established through the involvement of biology teachers in the development and selection of items that were directed at assessing the biology 10 curricular objectives. The biology teachers whose classes were involved in the research confirmed that the items were valid in terms of the program content.

Reliability of the test items during the development of the test was determined by submitting the pilot study student responses to the items to the documented *Itemanal R198 program from the Computing Services at the University of Alberta. Items with low biserial correlations were deleted or revised to alleviate weaknesses identified by the analysis. The research study student responses to the test items were submitted to the *Itemanal R198 test analysis program and the Kuder-Richardson 20 coefficient of reliability was determined to be 0.695.

Content validity for the posttest on science, society and technology was established through the development of items aimed at determining student achievement of the written cognitive objectives of the instructional unit and confirmed by a panel of judges. Further, after teaching the instructional unit to their treatment groups, the student teachers indicated that the test items were valid in that the students who gained an understanding of the concepts developed during the instruction of the unit or who were able to extend those concepts should be able to provide the correct responses to the test items.

In order to maximize the level of item and test reliability, the pilot study student responses to the science, society and technology test items were analyzed by the *Itemanal program from Computing Services at the University of Alberta. Those items with low biserial correlations were revised to alleviate threats to reliability which were identified by the analysis. The student responses to the revised test during the research study were also submitted for analysis by the *Itemanal R198 program and the Kuder-Richardson 20 coefficient of reliability was determined to be 0.536.

The student appraisal of student teacher questionnaire consisted of 20 items aimed at determining student perceptions of their student teachers' teaching effectiveness and questioning effectiveness. The items aimed at appraising teaching effectiveness were developed in relation to the five major factors identified by Trent and Cohen, 1973, to be consistently identified by students as being descriptors of effective teaching. The items aimed at appraising student teacher questioning effectiveness were developed to be consistent with the descriptors of effective use of questions identified by Orlich et al, 1980, and Blosser, 1973. The Cronbach α coefficient of reliability for the questionnaire was determined to be 0.86.

The activities associated with this study can best be summarized by a presentation of the activities in the chronological order in which they occurred during the study over the fourteen week university term, as follows:

1. Weeks 2 and 3: Student teachers studied Blosser's Question Category System for Science,

categorized questions according to the system, practiced preparing questions at different levels of the system and, during peer teaching, practiced using a question asking strategy which would facilitate their control of higher cognitive level question wait-time ranges.

2. Weeks 4 to 7: Student teachers were student teaching in junior high school science classes where they practiced using 1-4 and 4-7 second higher cognitive level question wait-time ranges and the appropriate question asking strategy.
3. Week 6: Administration of the biology 10 achievement test (see appendix B), to all students who were to be involved in the research study. The items on this test are aimed at measuring student achievement of the cognitive objectives of the biology 10 program. The results of this test served as the covariate measure.
4. Weeks 9 and 10: Revision of the instructional unit outline on the interrelationships of science, society and technology (see appendices M and N). Student teachers practiced the development, categorization, and use of different cognitive level questions. Student teachers also practiced the use of a question asking strategy which facilitates the control of higher cognitive

level question wait-time ranges. Finally, the research study student teachers' abilities in categorizing questions as to either recall or higher cognitive level, according to Blosser's Question Category System for Science, were determined during the tenth week.

5. Weeks 11 and 12: During these first two weeks of the four week round of student teaching with the senior high school treatment groups, the student teachers practiced the question asking strategy which facilitated their control of the higher cognitive level question wait-time ranges and attempted to use the two wait-time ranges with their classes.

6. Weeks 13 and 14: The student teachers taught the unit on the interrelationships of science, society and technology to each treatment group. They audiotaped their lessons, transcribed the questions used in each class, and categorized the questions as to cognitive level. The achievement test on the unit taught, and the questionnaire gaining student perceptions of their student teachers' effectiveness in teaching and using questions were administered by the student teachers during the class period following the treatments. Fifteen answer sheets which had

student responses to all instruments were randomly selected from each treatment group class for subsequent statistical analyses.

The treatment lesson audiotapes were played through a strip chart recorder to obtain graphic representations of verbal interactions and pauses during the presentation of the treatments. The wait-times for higher cognitive level questions were determined by linear measurements of the appropriate pauses as recorded on the strip charts.

The analysis of covariance (ANCV 15 program from the Division of Educational Research Services at the University of Alberta) was used to determine if the treatment groups differed in their achievement of the instructional unit cognitive objectives. Related questions concerning the interaction of student teacher familiarity with the instructional unit X wait-time range were investigated by analyzing the data using the two-way analysis of covariance (ANCV 25 program from the Division of Educational Research Services at the University of Alberta).

The Hotelling's T^2 (MULV 08 program from DERS) was used to compare the two treatment groups for student perceptions of their student teachers' effectiveness in teaching and in using questions. The student responses to individual items of the student appraisal of student teacher questionnaire were further analyzed in an effort to determine specific differences between treatment group perceptions of their student teachers for teaching effectiveness, questioning effectiveness and for each item of the questionnaire.

Summary of the Results

Table XXXI summarizes the decisions of the research hypotheses.

TABLE XXXI

SUMMARY OF DECISIONS MADE CONCERNING THE HYPOTHESES OF THE STUDY

Hypothesis	P	Decision: Tenable	Decision: Reject
H_1: There is no significant difference (α = 0.05) between the mean achievement level of grade XI biology student taught by biology student teachers using a 1-4 second higher cognitive level question wait-time range and the mean achievement level of students taught by the same student teachers using a 4-7 second higher cognitive level question wait-time range.	$<$ .001		+
H_2: There is no significant difference (α = 0.05) in the students perception of the effectiveness of biology student teachers who use a 1-4 second high cognitive level question wait-time range when compared to students perceptions of the effectivness of biology student teachers who use a 4-7 second high cognitive level question wait-time range.	.037		+

The results relating to Hypothesis H_1 are partially supported by Tobin (1980) and Riley (1980a), who found that students given longer question wait-time achieve at a higher level than those given a shorter question wait-time. However, the cited studies are not parallel to this research since they involved different grade levels of students and the question wait-time thresholds varied among the involved groups of teachers. Further, Tobin and Riley used average wait-times whereas this study used two question wait-time ranges.

The data associated with the testing of Hypothesis H_1 were further analyzed to determine whether there was significant interaction between first or second teaching of the instructional unit and the two higher cognitive level question wait-time ranges with student achievement. The two-way analysis of covariance (see table XXII) and the plot of the four group means corrected for the effect of the covariate (see table XXI and figure 5) indicated the following:

1. Students taught by a student teacher teaching the instructional unit for the second time using either the 1-4 second or 4-7 second higher cognitive level question wait-time range had significantly lower achievement ($P = 0.003$);
2. Students taught by a student teacher teaching the instructional unit for the first or second time using the 4-7 second higher cognitive level question wait-time range had a significantly higher achievement ($P < 0.001$); and

3. The interaction between first or second teaching of the instructional unit and higher cognitive level question wait-time range as related to student achievement was not significant ($P = 0.495$).

The analyses suggest that increased student achievement associated with their student teacher using a 4-7 second higher cognitive level question wait-time range was independent of the teachers' familiarity with the instructional unit. This suggestion is somewhat unexpected in that one would normally anticipate that student teachers would perform more effectively during a second presentation of an instructional unit in comparison to the first presentation of that unit. A possible explanation of this event lies in the fact that the student teachers were involved with the preparation of the instructional unit lessons over a long period of time. They may have become bored with it and performed less well during the second presentation.

With reference to the testing of Hypothesis H_2, the student perceptions of student teachers' effectiveness was lower for student teachers who used a 4-7 second higher cognitive level question wait-time range than for student teachers who used a 1-4 second higher cognitive level question wait-time range at the 0.037 level of significance. When the means of the student responses for the different variables of the student appraisal of student teachers are studied, various interesting specific student perceptions appear to be expressed. Students in the 4-7 second higher cognitive level question wait-time range groups believe that they were freer to disagree with their student teacher (see table XXIV, item 111), and that these student teachers used the class time less efficiently (see table XXIV, item 116). With the exception of those two items, students mean perceptions between the two groups for the items in the questionnaire were very similar. In fact, further analyses of the student responses to this questionnaire failed to identify specific items for which treatment group means were significantly different.

Conclusions

In drawing conclusions from this study, it must be noted that there are some major limitations associated with this research. Firstly, classroom research relates to the existence of numerous potentially contaminating variables over which a researcher has little or no control. Secondly, the student teachers involved in the research were not volunteers, and it cannot be assumed that their interest or conviction in this study was uniform. Thirdly, the student teachers who taught the treatment lessons on the interrelationships of science, society and technology used different examples, and different numbers of questions.

It is quite possible that the examples used by some student teachers were more meaningful to the students taught than the examples used by others. However, this variability in examples used might not have been a serious limitation since each student teacher served as his/her own control by presenting both treatments. Fourthly, different student teachers achieved different levels of success in using the required wait-time ranges during the treatment lessons.

A main aspect of the study was to determine the relationship which existed between higher cognitive level question wait-time range and student achievement. Student achievement tests developed during the study, and subsequently determined to have lower than desirable levels of reliability, were used for the data collection. The data from the tests were analyzed by analysis of covariance which determined a highly significant F-ratio ($P<0.001$) for the main treatment effect. This finding was confirmed by an analysis of variance which used the individual class sample as the experimental unit and determined a treatment effect F-ratio of 8.088 ($P<0.05$). These analyses were further supported when adjusted criterion test means from shorter wait-time treatment class samples were observed to be lower than the longer wait-time treatment class samples for six of the eight student teachers involved in the study. Even with the less than desirable levels of test reliability, the highly significant F-ratios for the main treatment effect lead to the conclusion that grade XI biology students given a 4-7 second higher cognitive level question wait-time range demonstrated higher levels of achievement than similar students given a 1-4 second higher cognitive level question wait-time range.

The other aspect of this study dealt with investigating whether student perceptions of student teachers who used a 4-7 second higher cognitive level question wait-time range were different from student perceptions of student teachers who used a 1-4 second higher cognitive level question wait-time range. The Hotelling's T^2 analysis of the student responses to the twenty item questionnaire used to gain the student perceptions, determined a significant F-ratio ($P=0.037$). By treating the instrument as an interval scale and comparing the overall means, the indication was that the students perceived student teachers who used a 4-7 second higher cognitive level question wait-time range as being less effective than student teachers who used a 1-4 second higher cognitive level question wait-time range. This indication may relate to the findings reported by Anderson (1978) who found that high school students who were taught facts and concepts in physics by teachers using an extended question wait-time had an increased apathy towards physics. However, confidence intervals were not determined during the analysis and the indication presented by comparing the overall means for the treatment groups may not be accurate and lead to erroneous conclusions.

Suggestions and Recommendations for Further Research

The statistical analyses that were used resulted in significant F-ratios. However, because of the apparent inequality between treatment groups, indicated by the highly significant F-ratio for the covariate determined during the analysis of covariance, and the absence of confidence intervals for the Hotelling's T^2 analysis, the findings do not lead to conclusive statements. The following suggestions which relate to further study in this area are presented with a view toward the alleviation of the deficiences existing in this research and in response to observations made during it.

Firstly, because of the methods by which students are placed in different classes in a school program, intact classes cannot be considered to be representative of a particular grade in a school and a random selection of students from one class may be quite different in many ways from a random selection of students from another class. Whenever possible, the students who are to be involved in a research study such as this one should be randomly sampled from the schools population rather than from intact classes. When such sampling is not possible, and analysis of covariance is suggested as a part of the research design, a concerted effort toward using a covariate measure which demonstrates a high level of correlation with the dependent measure should be made.

Secondly, the reliability levels of achievement tests are affected by a variety of factors, and test developers should avoid their influences during test development and revision procedures. Two main factors are the length of the test, and the variability of the item difficulty levels (Thorndike, 1971). Their effects indicate that test developers should make tests as long as the available test administration time permits, and should avoid the inclusion of items which have very high and low difficulty indices.

Finally, in research such as this, where an inequality between treatment groups is found to have existed prior to the treatments, procedures should be used to transform the scores in order to linearize the regression function and stabilize the error term variance (Neter and Wasserman, 1974, p.123). Such transformations assist in the satisfaction of assumptions regarding the normality of treatment groups which is necessary for most statistical procedures (Dixon and Massey, 1969, p.323).

Much of the classroom based research on the effects of varied teacher question wait-times is dependent on the ability of the involved teachers to extend and control their wait-times. During this study, it was indicated that some student teachers were able to control their wait-time ranges. It is recommended that further efforts be directed at developing training methods which would effectively and efficiently facilitate teacher attainment of such skills.

In the process of research on extended teacher question wait-times, and the description of such research, certain aspects appear to require further consideration. For instance, treatments associated with teacher question wait-time research can be described in terms of mean wait-times, or in terms of wait-time ranges. Each has both merits and inadequacies. For example, two teachers who have mean wait-times of 4 seconds may be identified as having identical question wait-times. However, if one teacher has a wait-time range of 0.5 to 8.0 seconds, and the other teacher has a wait-time range of 3 to 5 seconds, their use of question wait-times is very different. Similarly, two teachers who use the same wait-time range may have very different mean wait-times. In view of the findings, it would be most appropriate and elucidating if researchers described teacher question wait-time treatments in terms of mean wait-times, and wait-time ranges.

Another aspect of the research associated with extended teacher question wait-time that requires further consideration pertains to the cognitive level of the questions asked during the treatments. The functioning of questions in the learning-teaching process in two classes where the teachers use mean wait-times of 4 seconds are very different if one class has 60 percent of the questions asked at the recall level and the other has only 20 percent at that level.

An important aspect of any classroom-based research which involves students is the determination of student perceptions regarding the treatments. It is recommended that teachers who practice extended question wait-times occasionally have their students appraise their teaching techniques in ways which provide some indication regarding the students' perceptions of their techniques, with specific reference to the wait-times they are using. Such knowledge of student perceptions may assist teachers in arriving at optimal question wait-times with their classes.

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APPENDICES

APPENDIX A

PILOT STUDY COVARIATE ACHIEVEMENT TEST

GENERAL INFORMATION

This achievement test attempts to cover the major objectives in the biology 10 program.

DIRECTIONS:

Use an ordinary HB pencil only.

Fill in the information at the top of the answer sheet as directed by the examiner.

Read each item carefully and decide which of the alternatives BEST completes the statement, or answers the question. Locate that item number on the answer sheet and fill in the space that corresponds to the alternative that you have chosen.

Mark your answers according to the instructions and the illustration given on the answer sheet. Avoid placing any marks among the black timing lines along the bottom margin of the answer sheet.

Mark only one answer for each item. If you wish to change an answer, be sure that your original choice has been completely erased.

Do not fold or bend the answer sheet.

Return complete TEST BOOKLET and ANSWER SHEET at the end of the test period.

1. Chloroplasts in a green plant cell move mainly because of

   A. Brownian motion
   B. cytoplasmic streaming
   C. active transport
   D. diffusion

2. Nutrients are best described as substances which are

   A. required by all organisms for their metabolic reactions
   B. organic in nature
   C. inorganic in nature
   D. classed as carbohydrates, lipids and proteins

3. An organism with a dorsal nerve cord, a notochord and gill slits would be found in the phylum

   A. Chordata
   B. Coelenterata
   C. Porifera
   D. Mollusca

4. Organisms are primarily classified according to similarities in

   A. behavior
   B. environmental habitat
   C. reproduction
   D. structure

5. It is essential that intestinal parasites have

   A. an efficient digestive system
   B. a chemically resistant cuticle
   C. a minutely small body
   D. powerful digestive enzymes

6. When placed in a dish of water, an earthworm will die because

   A. it depends on decaying vegetation for its food supply
   B. its muscles are not developed sufficiently to enable it to swim
   C. it cannot obtain enough oxygen from the water
   D. its epidermis allows too much water to leave

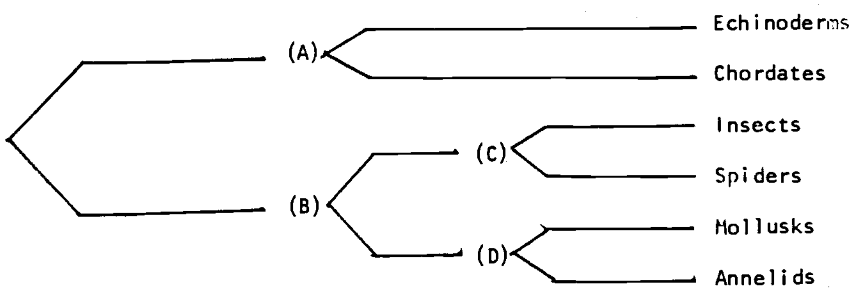
7. The simplest animals having centralized nervous tissue belong to the phylum

   A. Coelenterata
   B. Platyhelminthes
   C. Porifera
   D. Chordata

8. Young shrubs and trees die if animals frequently eat their leaves because

   A. the plants cannot get sufficient moisture
   B. water evaporates too rapidly
   C. the plants cannot manufacture sufficient food
   D. disease-causing bacteria enter the wounded leaves

Use the information below to answer items 9 and 10.



A, B, C and D represent junctions at which organisms may be separated into different groups according to anatomical characteristics.

Choose the letter for the junction which best suits each of the following statements.

9. Organisms with six legs are separated from those with eight legs.

10. Organisms with jointed appendages are separated from those without jointed appendages.

11. The following observations were made while studying a unicellular organism under a microscope. The organism contained a nucleus, a cell membrane, chloroplast structures and a flagellum. Based on these data the organism would most likely be

    A. a euglena
    B. an ameba
    C. a paramecium
    D. a virus

12. If a student in biology was classifying the timber wolf, he would write *Canis lupus*. These two latin words represent the

    A. phylum and class
    B. genus and species
    C. class and order
    D. family and genus

13. Adult porifera illustrate an advancement over protozoa because the porifera

    A. use aerobic respiration
    B. have cellular specialization
    C. have locomotion
    D. possess cell nuclei

Use the information and table below to answer items 14 and 15.

A biology student had been given three unknown samples X, Y, Z and instructed to determine whether or not they contained starch. The student was also given a reddish-orange solution (Lugols' iodine solution) that tested for starch. He began his experiment by collecting samples of the following items: starch, potato, bread and distilled water. The student then placed his samples in separate clean test tubes and added two to four drops of the given solution to each test tube. He then recorded the following observations.

SAMPLE	COLOR AFTER ADDING DROPS OF SOLUTION
starch	purple
potato	dark purple
bread	purple
distilled water	reddish brown
X	purple
Y	dark purple
Z	reddish brown

14. A control used in this experiment was the

    A. distilled water
    B. Lugols' iodine solution
    C. potato
    D. sample X

15. A possible source of variability in the data might be due to the

    A. separate test tubes used for the different materials
    B. distilled water
    C. cleaned test tubes
    D. amount of Lugols' solution added

16. In flowering plants transpiration occurs primarily from the

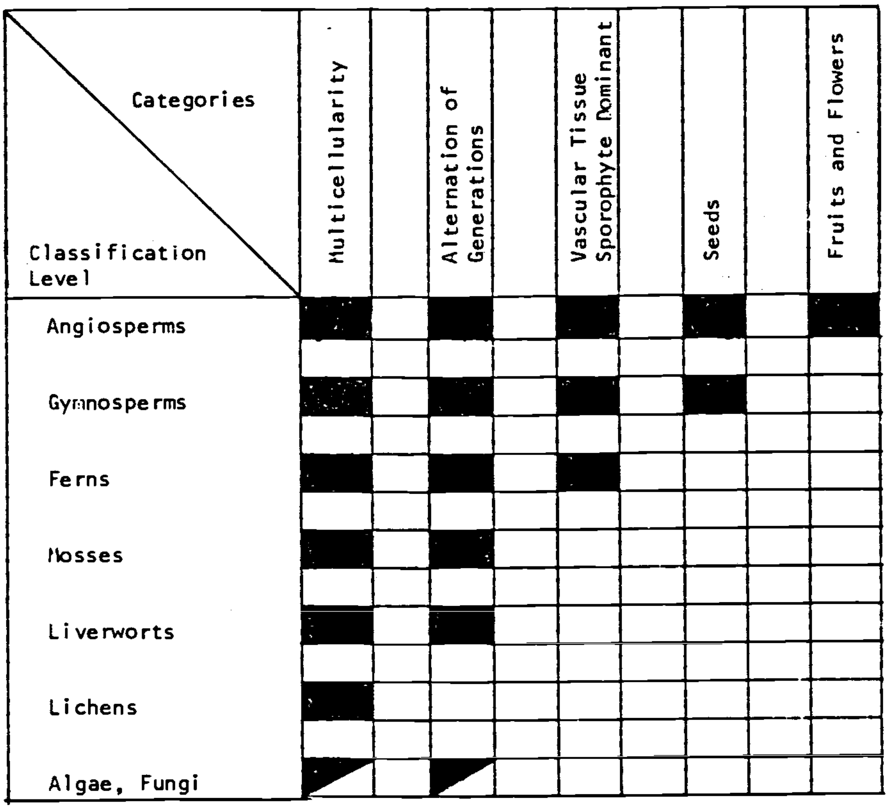
    A. roots
    B. petals
    C. stems
    D. leaves

17. Ribosomes are associated with

    A. cell respiration
    B. DNA production
    C. protein synthesis
    D. growth secretions

Use the information and chart below to answer items 18 and 19.

The 'simplicity versus complexity' concept cannot be overlooked if representatives of the plant kingdom are studied. The chart below presents a graphic representation of the 'accumulation principle' with regard to several important features of plants. Open squares mean 'characteristic lacking', shaded squares mean 'characteristic present in some species'.



18. The most complex plant form NOT possessing specialized water conducting tissue is the

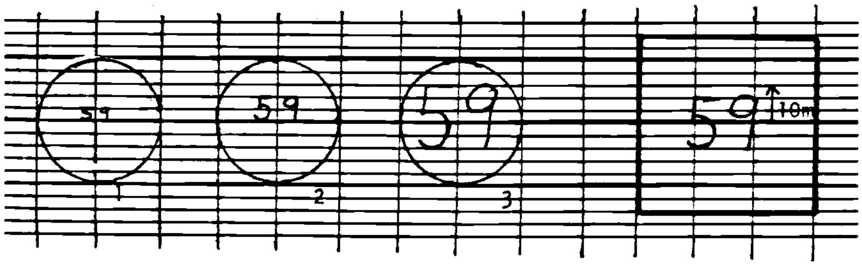
    A. angiosperms
    B. ferns
    C. mosses
    D. algae

19. The unique characteristic of angiosperms is associated with the process of

    A. nutrition
    B. locomotion
    C. growth
    D. reproduction

Use the following information and diagrams to answer items 20 to 23.

The 3 circles represent 3 microscopic fields of view in which the number 59 is being examined. In the square at the right, the number is shown as drawn by a student. Diameter of field of view No. 2 is 1.6 mm.



20. The size of the actual number 59 being examined is approximately

    A. 0.01 mm
    B. 0.4 mm
    C. 1.6 mm
    D. 8.0 mm

21. How many times is the drawing magnified in relation to the original object?

    A. 0.4x
    B. 25 x
    C. 40 x
    D. 160 x

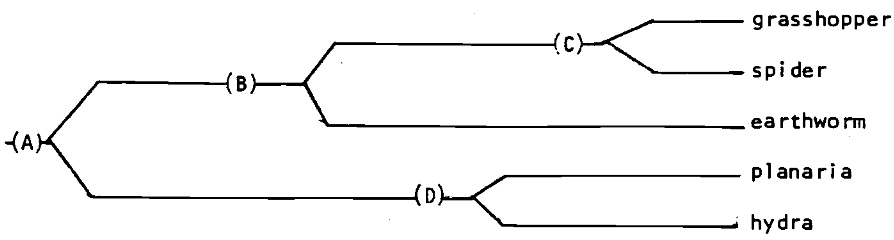
22. If the object in field of view 3 is being magnified approximately 480 times and the objective lens magnifies 40 times, the ocular lens is magnifying _____ times.

    A. 12
    B. 460
    C. 540
    D. 20,000

23. In addition to the highest magnification, field of view number 3 also shows the best

    A. degree of fine adjustment
    B. illumination
    C. three-dimensional view
    D. resolving power

Use the information below to answer items 24 and 25.



A, B, C, and D represent junctions at which organisms may be separated into different groups according to anatomical characteristics.

Choose the letter for the junction which best suits each of the following statements.

24. Organisms with bilateral symmetry are separated from those without bilateral symmetry.

25. Organisms with an anus are separated from those without an anus.

26. The following observations were made on a particular organism. The organism

    1. had a fully developed backbone
    2. was cold-blooded
    3. was totally aquatic
    4. laid eggs without a protective shell

    Based on these observations the organism would most likely be found in the taxonomic class

    A. Amphibia
    B. Crustacea
    C. Osteichthyes
    D. Reptilia

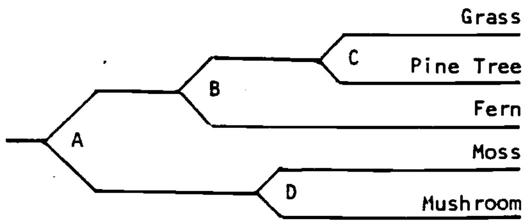
27. The many types of domesticated cats Felis domestica, are referred to as different varieties rather than different species. The main reason for this is that

    A. a species refers to wilderness animals
    B. all cats can interbreed with each other
    C. all cats are very similar physiologically
    D. a variety refers to domesticated animals

28. The greatest similarity would be found in organisms belonging to the same

    A. class
    B. family
    C. order
    D. phylum

Use the information below to answer items 29 to 35.



A, B, C and D represent junctions at which organisms may be separated into different groups according to anatomical characteristics.

Choose the letter for the junction which best suits each of the following statements.

29. Organisms with chlorophyll are separated from those without chlorophyll.

30. Plants with true roots, stems and leaves are separated from those lacking such tissues.

31. Plants in which seeds develop within a pistil are separated from plants where seeds do not develop within a pistil.

32. Plants having flowers are separated from plants with no flowers.

33. Plants having seeds are separated from plants having spores.

34. Plants having cones are separated from plants lacking cones.

35. Junction D distinguishes between members of different

    A. phyla
    B. subphyla
    C. classes
    D. subclasses

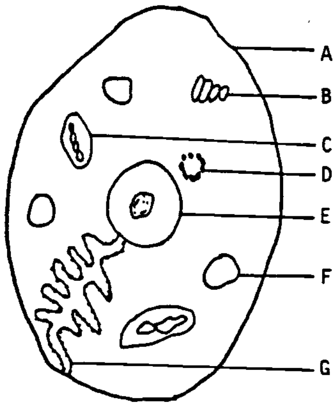
36. Members of the phylum which undergo the most pronounced change in symmetry between young and adult stages are

    A. chordates
    B. annelids
    C. echinoderms
    D. coelenterates

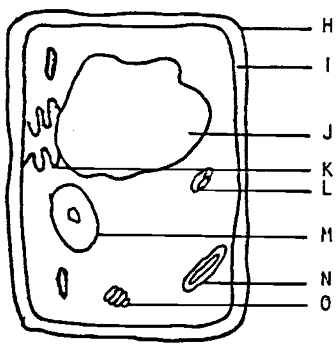
37. Animals which reproduce by external fertilization generally

    A. live in or near water
    B. provide protection for the newborn
    C. produce fewer, stronger offspring
    D. are hermaphroditic

Use the following diagrams to answer items 38 to 41.



Cell X



Cell Y

38. When viewing an Elodea leaf under a microscope, the most noticeable structure is

    A. D
    B. G
    C. J
    D. L

39. The part of a cell which functions as a "powerhouse" is indicated by structure

    A. D
    B. F
    C. N
    D. O

40. The structure which has been observed in a rabbit cell but not in a pea plant cell is

    A. D
    B. F
    C. G
    D. L

41. The "master" molecules of the cell are located in structures

    A. F and J
    B. E and M
    C. C and D
    D. B and N

Use the information in the following table to answer items 42 to 45.

Animal I	Animal II	Animal III	Animal IV	Animal V
Hair Backbone Claws	Feathers Backbone Claws	Hair Backbone No claws	Scales Backbone Claws	Shell Muscular foot

42. Animals I through IV all belong to the group of animals called

    A. echinoderms
    B. invertebrates
    C. vertebrates
    D. molluscs

43. The number of classes or organisms represented by animals I through IV is

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

44. Animal V belongs in the phylum

    A. Mollusca
    B. Annelida
    C. Echinodermata
    D. Chordata

45. Animal IV cannot be a fish because it has

    A. scales and therefore no fins
    B. claws and therefore legs
    C. a backbone and therefore is a vertebrate
    D. a backbone and therefore is a land animal

Use the following information to answer items 46 to 51.

Two cages of mice were set up under identical conditions. 8 mice (4 male and 4 female) were placed in each cage. Cage one received unlimited food and water. Cage 2 received a measured amount of food and water each day. All other conditions were the same in both cages. The populations were allowed to increase for 1 year.

46. The problem in this experiment could be stated as

    A. How does limited space affect population density?
    B. How does unlimited food and water affect population density?
    C. How does the amount of available food and water affect population density?
    D. Do mice reproduce when placed in cages?

47. The following prediction as to the outcome that might be an accurate one is

    A. Both populations will decrease
    B. The population of cage 2 will starve to extinction
    C. The population of cage 1 will increase unchecked
    D. The population of cage 2 will increase and then stablize

48. The variable present in this situation is

    A. space
    B. food and water
    C. size of the mouse
    D. space and food

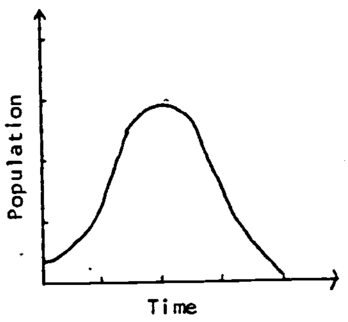
49. An INCORRECT way of handling the data is

    A. present it in written form
    B. express it in tabulated form
    C. illustrate the data by the use of graphs
    D. compare two sets of data, one set from this study and one set from another

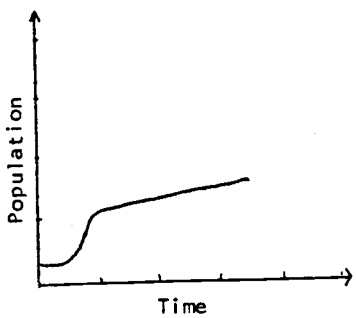
50. If the data showed that the mice in cage 1 has ceased reproducing and were engaging in fighting and cannabalism, one could conclude that

    A. a dietary deficiency existed
    B. the mice had become fat from overeating
    C. the feamles had lost interest in reproducing
    D. the overcrowding caused a change in behavior

51. The graphs below represent the mice population of the two cages during the study.



Cage 1



Cage 2

On the data represented in the graphs, the most reasonable conclusion might be

A. Mice undergo a behavioral change if there is unlimited food and water
B. The population will level off to stability
C. Space and available food are limiting factors to a population
D. Mice died because of a shortage of space

52. When changing the magnification of a microscope, the factor that does NOT change is the

A. brightness of the field
B. resolving power
C. diameter of the field
D. position of the object viewed

Use the information below to answer items

Under natural conditions, the major fish predator on fresh water perch is a larger fish called the pike. When pike are within a given distance of perch, the perch are observed to group or school near the bottom of the lake with fins erect. A biologist, observing these activites, formed the following hypothesis: Organic chemicals produced by the pike are released into the water and detected by the perch causing their reaction. He then performed several experiments to test the hypothesis.

EXPERIMENT 1 Several perch were put into an aquarium from which several pike had just been removed.

EXPERIMENT 2 The water in an aquarium from which pike had been removed was carefully treated to remove organic chemicals and perch were placed in the aquarium.

53. When the biologist performed Experiment 1, he found that the perch grouped near the bottom with fins erect. This observation

A. proves that the hypothesis is correct
B. proves that the hypothesis is incorrect
C. supports the hypothesis but does not prove it
D. is irrelevant as far as this hypothesis is concerned

54. If the perch did not group near the bottom with fins erect in Experiment 2, this observation would

    A. further support the hypothesis but not prove it
    B. show conclusively that the hypothesis is incorrect
    C. contradict the results from Experiment 1
    D. show conclusively that the hypothesis is correct

55. If the perch in Experiment 2 grouped near the bottom with fins erect, this observation would

    A. neither support nor disprove the hypothesis
    B. show conclusively that the hypothesis is correct
    C. further support the hypothesis but not prove it
    D. show conclusively that the hypothesis is incorrect

APPENDIX B

RESEARCH STUDY COVARIATE ACHIEVEMENT TEST

GENERAL INFORMATION

This achievement test attempts to cover the major objectives in the biology 10 program.

DIRECTIONS:

Use an ordinary HB pencil only.

Fill in the information at the top of the answer sheet as directed by the examiner.

Read each item carefully and decide which of the alternatives BEST completes the statement, or answers the question. Locate that item number on the answer sheet and fill in the space that corresponds to the alternative that you have chosen.

Mark your answers according to the instructions and the illustration given on the answer sheet. Avoid placing any marks among the black timing lines along the bottom margin of the answer sheet.

Mark only one answer for each item. If you wish to change an answer, be sure that your original choice has been completely erased.

Do not fold or bend the answer sheet.

Return complete TEST BOOKLET and ANSWER SHEET at the end of the test period.

1. Which of the following is NOT a true statement about plant and animal cells?

   A. Plant cells have cell walls, animal cells do not
   B. Plant cells have plastids, animal cells do not
   C. Plant cells have lysosomes, animal cells do not
   D. Plant cells generally do not have centrioles, animal cell do

2. Nutrients are best described as substances which are

   A. required by all organisms for life
   B. organic in nature
   C. inorganic in nature
   D. classed as carbohydrates, lipids and proteins

3. An organism with a dorsal nerve cord, a notochord and gill slits would be found in the phylum

   A. Chordata
   B. Coelenterata
   C. Porifera
   D. Mollusca

4. Organisms are primarily classified according to similarities in

   A. behavior
   B. environmental habitat
   C. reproduction
   D. structure

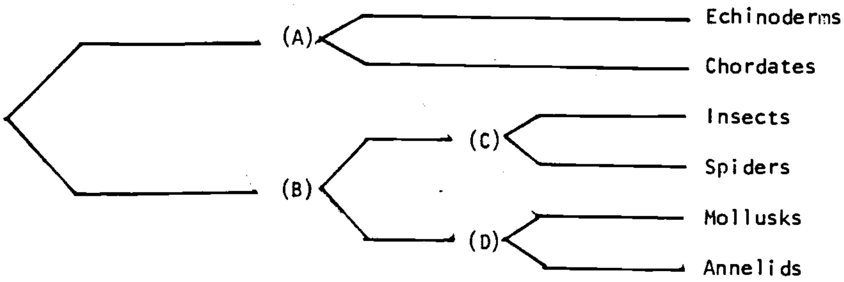
5. It is essential that intestinal parasites have

   A. an efficient digestive system
   B. a chemically resistant cuticle
   C. a minutely small body
   D. powerful digestive enzymes

6. When placed in a dish of water, an earthworm will die because

   A. it depends on decaying vegetation for its food supply
   B. its muscles are not developed sufficiently to enable it to swim
   C. it cannot obtain enough oxygen from the water
   D. its epidermis allows too much water to leave

Use the information below to answer items 7 and 8.



A, B, C and D represent junctions at which organisms may be separated into different groups according to anatomical characteristics.

Choose the letter for the junction which best suits each of the following statements.

7. Organisms with six legs are separated from those with eight legs.

8. Organisms with jointed appendages are separated from those without jointed appendages.

9. The following observations were made while studying a unicellular organism under a microscope. The organism contained a nucleus, a cell membrane, chloroplast structures and a flagellum. Based on these data the organism would most likely be

   A. a euglena
   B. an ameba
   C. a paramecium
   D. a virus

10. If a student in biology was classifying the timber wolf, he would write *Canis lupus*. These two latin words represent the

   A. phylum and class
   B. genus and species
   C. class and order
   D. family and genus

11. Adult sponges illustrate an advancement over protozoa because the sponges

    A. use oxygen from the atmosphere
    B. have different kinds of cells
    C. have locomotion
    D. possess cell nuclei

Use the information and table below to answer items 12 and 13.

A biology student had been given three unknown samples X, Y, Z and instructed to determine whether or not they contained starch. The student was also given a reddish-orange solution (Lugols' iodine solution) that tested for starch. He began his experiment by collecting samples of the following items: starch, potato, bread and distilled water. The student then placed his samples in separate clean test tubes and added two to four drops of the given solution to each test tube. He then recorded the following observations.

SAMPLE	COLOR AFTER ADDING DROPS OF SOLUTION
starch	purple
potato	dark purple
bread	purple
distilled water	reddish brown
X	purple
Y	dark purple
Z	reddish brown

12. A control used in this experiment was the

    A. distilled water
    B. Lugols' iodine solution
    C. potato
    D. sample X

13. A possible source of variability in the data might be due to the

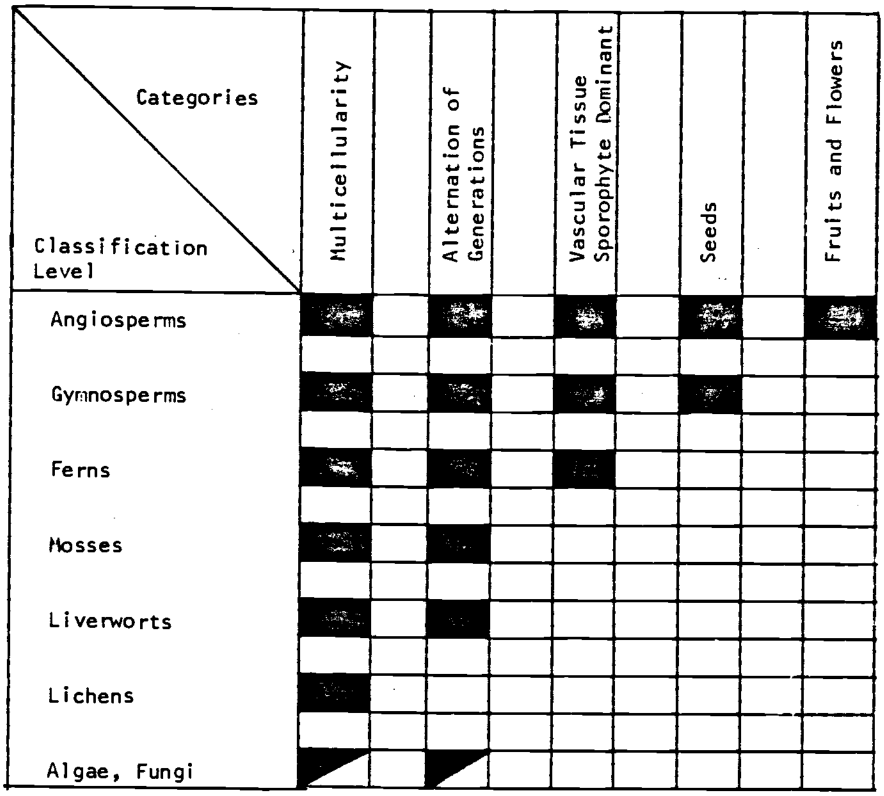
    A. separate test tubes used for the different materials
    B. distilled water
    C. cleaned test tubes
    D. amount of Lugols' solution added

14. In flowering plants loss of water occurs primarily from the

    A. roots
    B. petals
    C. stems
    D. leaves

Use the information and chart below to answer items 15 and 16.

The 'simplicity versus complexity' concept cannot be overlooked if representatives of the plant kingdom are studied. The chart below presents a graphic representation of the 'accumulation principle' with regard to several important features of plants. Open squares mean 'characteristic lacking', shaded squares mean 'characteristic present in some species'.



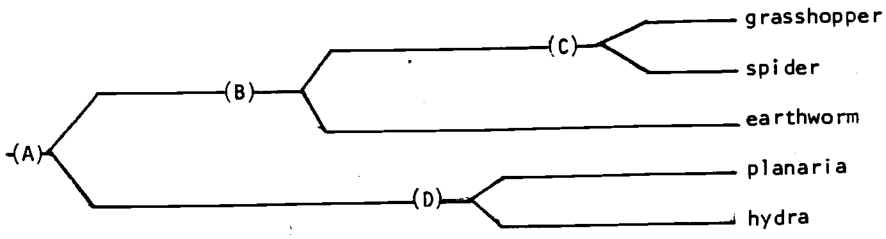
15. The most complex plant form NOT possessing specialized water conducting tissue is the

    A. angiosperms
    B. ferns
    C. mosses
    D. algae

16. The unique characteristic of angiosperms is associated with the process of

    A. nutrition
    B. locomotion
    C. growth
    D. reproduction

Use the information below to answer items 17 and 18.



A, B, C, and D represent junctions at which organisms may be separated into different groups according to anatomical characteristics.

Choose the letter for the junction which best suits each of the following statements.

17. Organisms with bilateral symmetry are separated from those without bilateral symmetry.

18. Organisms with an anus are separated from those without an anus.

19. The following observations were made on a particular organism. The organism

    1. had a fully developed backbone
    2. was cold-blooded
    3. was totally aquatic
    4. laid eggs without a protective shell

    Based on these observations the organism would most likely be found in the taxonomic class

    A. Amphibia
    B. Crustacea
    C. Osteichthyes
    D. Reptilia

20. The many types of domesticated cats Felis domestica, are referred to as different varieties rather than different species. The main reason for this is that

    A. a species refers to wilderness animals
    B. all cats can interbreed with each other
    C. all cats are very similar physiologically
    D. a variety refers to domesticated animals

21. The greatest similarity would be found in organisms belonging to the same

    A. class
    B. family
    C. order
    D. phylum

22. A functional difference between cell walls and cell membranes is

    A. Walls occur on plant cells, cell membranes on animal cells
    B. Cell walls are thick, cell membranes are thin
    C. Cell membranes control molecular traffic, cell walls give support
    D. Cell membranes are living material, cell walls are nonliving material

23. Spores produced by some bacteria are

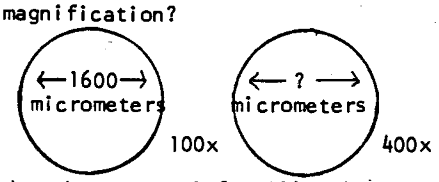
    A. readily killed by freezing
    B. produced to survive adverse conditions
    C. their usual means of reproduction
    D. the site of toxin synthesis

24. The body plan for the majority of organisms capable of movement is

    A. asymmetrical
    B. radially symmetrical
    C. spherically symmetrical
    D. bilaterally symmetrical

25. The figure below shows the field diameter of a microscope at 100x magnification. What would be the field diameter of the microscope at 400x magnification?

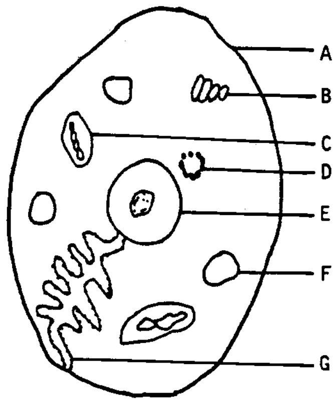
    A. 400
    B. 800
    C. 3200
    D. 6400



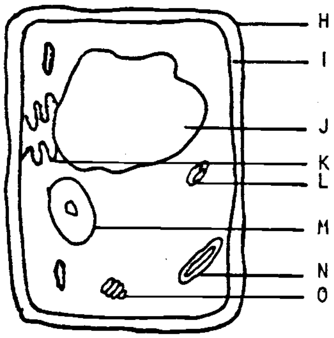
26. Animals which reproduce by external fertilization generally

    A. live in or near water
    B. provide protection for the newborn
    C. produce fewer, stronger offspring
    D. are hermaphroditic

Use the following diagrams to answer items 27 to 29.



Cell X



Cell Y

27. The part of a cell which functions as a "powerhouse" is indicated by structure

A. D.
B. F
C. N
D. O

28. The structure which has been observed in a rabbit cell but not in a pea plant cell is

A. D
B. F
C. G
D. L

29. The "master" molecules of the cell are located in structures

A. F and J
B. E and M
C. C and D
D. B and N

Use the information in the following table to answer items 30 to 32.

Animal I	Animal II	Animal III	Animal IV	Animal V
Hair Backbone Claws	Feathers Backbone Claws	Hair Backbone No claws	Scales Backbone Claws	Shell Muscular foot

30. The number of classes of organisms represented by animals I through IV is

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

31. Animal V belongs in the phylum

A. Mollusca
B. Annelida
C. Echinodermata
D. Chordata

32. Animal IV cannot be a fish because it has

    A. scales and therefore no fins
    B. claws and therefore legs
    C. a backbone and therefore is a vertebrate
    D. a backbone and therefore is a land animal

Use the following information to answer items 33 to 36.

Two cages of mice were set up under identical conditions. 8 mice (4 male and 4 female) were placed in each cage. Cage one received unlimited food and water. Cage 2 received a measured amount of food and water each day. All other conditions were the same in both cages. The populations were allowed to increase for 1 year.

33. The problem in this experiment could be stated as

    A. How does limited space affect population density?
    B. How does unlimited food and water affect population density?
    C. How does the amount of available food and water affect population density?
    D. Do mice reproduce when placed in cages?

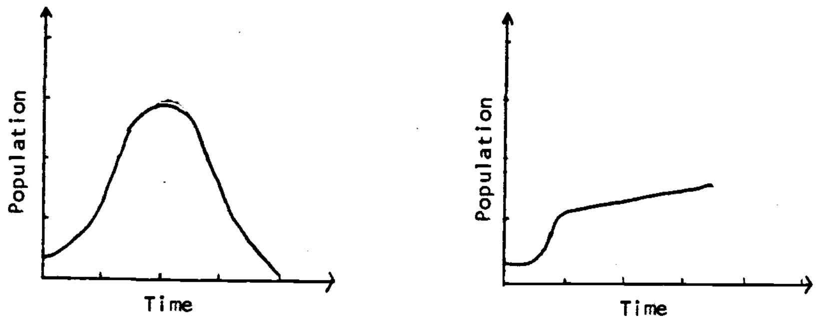
34. The variable present in this situation is

    A. space
    B. food and water
    C. size of the mouse
    D. space and food

35. If the data showed that the mice in cage 1 had ceased reproducing and were engaging in fighting and cannabalism, the best conclusion would be that

    A. a dietary deficiency existed
    B. the mice had become fat from overeating
    C. the females had lost interest in reproducing
    D. the overcrowding caused a change in behavior

36. If the graphs below represent the mice population of the two cages during the study,



Cage 1 Cage 2

then the most reasonable conclusion would be

A. Mice undergo a behavioral change if there is unlimited food and water
B. The population will level off to stability
C. Space and available food are limiting factors to a population
D. Mice died because of a shortage in space

37. When changing the magnification of a microscope, the factor that does NOT change is the

A. brightness of the field
B. resolving power
C. diameter of the field
D. position of the object viewed

Use the information below to answer items 38 to 40.

Under natural conditions, the major fish predator on fresh water perch is a larger fish called the pike. When pike are within a given distance of perch, the perch are observed to group or school near the bottom of the lake with fins erect. A biologist, observing these activites, formed the following hypothesis: Organic chemicals produced by the pike are released into the water and detected by the perch causing their reaction. He then performed several experiments to test the hypothesis.

EXPERIMENT 1	Several perch were put into an aquarium from which several pike had just been removed.
EXPERIMENT 2	The water in an aquarium from which pike had been removed was carefully treated to remove organic chemicals and perch were placed in the aquarium.

38. When the biologist performed Experiment 1, he found that the perch grouped near the bottom with fins erect. This observation

    A. proves that the hypothesis is correct
    B. proves that the hypothesis is incorrect
    C. supports the hypothesis but does not prove it
    D. is irrelevant as far as this hypothesis is concerned

39. If the perch did not group near the bottom with fins erect in Experiment 2, this observation would

    A. further support the hypothesis but not prove it
    B. show conclusively that the hypothesis is incorrect
    C. contradict the results from Experiment 1
    D. show conclusively that the hypothesis is correct

40. If the perch in Experiment 2 grouped near the bottom with fins erect, this observation would

    A. neither support nor disprove the hypothesis
    B. show conclusively that the hypothesis is correct
    C. further support the hypothesis but not prove it
    D. show conclusively that the hypothesis is incorrect

APPENDIX C

SAMPLE OF *ITEMANAL R198 PRINT-OUT FOR ITEMS FROM COVARIATE ACHIEVEMENT TEST

ITEM 31: DIF=0.767, RPB= 0.293, CRPB= 0.211 (95% CON= 0.087, 0.329)
RBIS= 0.405, CRBIS= 0.292, IRI=0.124

GROUP	N	INV	NF	OMIT	1*	2	3	4	5
TOTAL	240	1	0	1	0.77	0.04	0.13	0.05	0.0
HIGH	71	0			0.92	0.0	0.07	0.01	0.0
MID	102	1			0.76	0.07	0.11	0.05	0.0
LOW	67	0			0.61	0.04	0.24	0.10	0.0
TEST SCORE MEANS					23.57	21.00	19.91	19.46	0.0
DISCRIMINATING POWER					0.30	-0.04	-0.17	-0.09	0.0
STANDARD ERROR OF D.P.					0.03	0.00	0.01	0.01	0.0

ITEM 32: DIF=0.858, RPB= 0.253, CRPB= 0.185 (95% CON= 0.060, 0.305)
RBIS= 0.394, CRBIS= 0.288, IRI=0.088

GROUP	N	INV	NF	OMIT	1	2*	3	4	5
TOTAL	240	0	0	0	0.01	0.86	0.10	0.03	0.0
HIGH	71	0			0.01	0.97	0.01	0.0	0.0
MID	102	0			0.01	0.87	0.10	0.02	0.0
LOW	67	0			0.0	0.72	0.19	0.09	0.0
TEST SCORE MEANS					26.50	23.26	19.46	18.00	0.0
DISCRIMINATING POWER					0.01	0.26	-0.18	-0.09	0.0
STANDARD ERROR OF D.P.					0.00	0.03	0.01	0.01	0.0

ITEM 33: DIF=0.779, RPB= 0.295, CRPB= 0.214 (95% CON= 0.090, 0.332)
RBIS= 0.412, CRBIS= 0.299, IRI=0.122

GROUP	N	INV	NF	OMIT	1	2	3*	4	5
TOTAL	240	0	0	0	0.05	0.15	0.78	0.01	0.0
HIGH	71	0			0.0	0.10	0.90	0.0	0.0
MID	102	0			0.05	0.16	0.77	0.02	0.0
LOW	67	0			0.12	0.21	0.66	0.01	0.0
TEST SCORE MEANS					17.38	20.70	23.54	20.67	0.0
DISCRIMINATING POWER					-0.12	-0.11	0.24	-0.01	0.0
STANDARD ERROR OF D.P.					0.01	0.01	0.03	0.00	0.0

ITEM 34: DIF=0.717, RPB= 0.331, CRPB= 0.243 (95% CON= 0.120, 0.359)
RBIS= 0.440, CRBIS= 0.324, IRI=0.149

GROUP	N	INV	NF	OMIT	1	2*	3	4	5
TOTAL	240	0	0	0	0.08	0.72	0.03	0.17	0.0
HIGH	71	0			0.07	0.87	0.01	0.04	0.0
MID	102	0			0.07	0.72	0.04	0.18	0.0
LOW	67	0			0.12	0.55	0.04	0.28	0.0
TEST SCORE MEANS					20.55	23.80	20.75	19.63	0.0
DISCRIMINATING POWER					-0.05	0.32	-0.03	-0.24	0.0
STANDARD ERROR OF D.P.					0.01	0.02	0.00	0.01	0.0

ITEM 35: DIF=0.675, RPB= 0.116, CRPB= 0.025 (95% CON= -0.102, 0.151)
RBIS= 0.151, CRBIS= 0.033, IRI=0.054

GROUP	N	INV	NF	OMIT	1	2	3	4*	5
TOTAL	240	0	0	0	0.25	0.03	0.04	0.67	0.0
HIGH	71	0			0.20	0.01	0.04	0.75	0.0
MID	102	0			0.25	0.04	0.04	0.68	0.0
LOW	67	0			0.31	0.04	0.04	0.60	0.0
TEST SCORE MEANS					21.97	20.13	22.70	23.15	0.0
DISCRIMINATING POWER					-0.12	-0.03	-0.00	0.15	0.0
STANDARD ERROR OF D.P.					0.01	0.00	0.01	0.02	0.0

APPENDIX D

PILOT STUDY ACHIEVEMENT TEST ON SCIENCE, SOCIETY AND TECHNOLOGY

POST-TEST

SCIENCE/TECHNOLOGY/SOCIETY

NOTE: Some items in this test are related to material that is more advanced than the information presented or discussed during class. Make an effort to use ideas and information from discussions on this topic to select your answers.

Directions

- Use an ordinary HB pencil only.

- Fill in all information on the left portion of Side 1 of the answer sheet.

- Read each item carefully and decide which of the alternatives BEST completes the statement, or answers the question. Locate that item number on the answer sheet and fill in the space that corresponds to the alternative that you have chosen.

- Mark your answers according to the instructions and the illustration given on Side 2 of the answer sheet. Avoid placing any marks among the black timing lines along the bottom margin of the answer sheet.

- Mark only one answer for each item. If you wish to change an answer, be sure that your original choice has been completely erased.

- Do not fold or bend the answer sheet.

- Return complete TEST BOOKLET and ANSWER SHEET at the end of the test period.

1. Technology is best defined as

   A. the mother of science
   B. the daughter of science
   C. using aids for doing things
   D. a source of answers to societal needs

2. The taming of fire did NOT have a direct influence on

   A. man's struggle against predators
   B. man's survival at greater altitudes
   C. the diet that man could have
   D. the development of cities

3. Initially, the taming of fire resulted with man

   A. contolling part of his environment and fitting it to his needs
   B. beginning to constantly improve his environment
   C. becoming exposed to a greater variety of bacteria
   D. becoming exposed to greatly increased levels of carbon monoxide

4. Man could live in permanent villages only after he could be sure of

   A. a continued food supply
   B. a constant climate
   C. protection against invaders
   D. good soil for growing food

5. Probably the first people, before agriculture developed, to live in permanent villages were

   A. hunters
   B. barbarians
   C. herdsmen
   D. fishermen

6. Scientific ideas are general ideas that

   A. are used as sources of fact
   B. enable the prediction of new facts and relationships
   C. are known as hypotheses
   D. have been proved conclusively and remain unchanged

7. The ability of humans to make and use tools depends upon their

   A. taming of fire, hand-eye coordination and intelligence
   B. upright posture, growing of food and intelligence
   C. taming of fire, growing of food and intelligence
   D. hand-eye coordination, upright posture and intelligence

8. Technological advances have produced changes in man's way of

   A. observing his environment
   B. living
   C. adapting to his environment
   D. testing knowledge

For the next 6 questions consider the following information:

> Since about the year 1700, the world population has increased at a rapid rate. Agricultural efficiency has greatly improved the quality and quantity of food. The standard of living in many parts of the world has improved. Life span expectancy has increased in modern nations. Many diseases have been conquered by medical technology.
>
> QUESTION: Why then are many people as concerned about the future of the biosphere?

Use the key below to classify each of the statements that follow.

Key: A. A serious situation that exists now
     B. A situation that should not affect the question
     C. A situation that may need further investigating
     D. A false statement

9. People have different ideas about how to solve pollution problems.

10. Modern science and technology can help solve many problems facing mankind.

11. Wars are an answer to over population.

12. Scientists can solve most, if not all, of the world's problems.

13. Solar energy can be used more efficiently.

14. People of all nations are equally well fed.

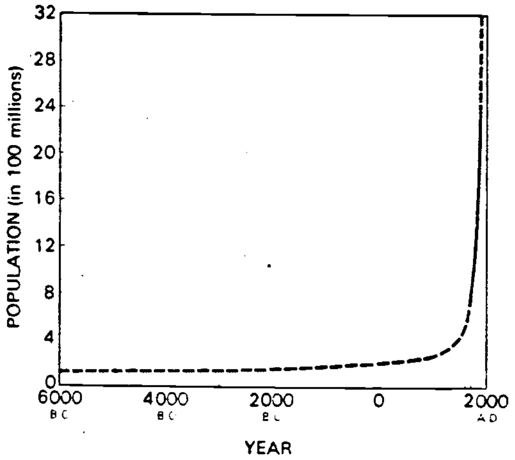
15. The use of fire has had the least direct influence on

   A. technological advances
   B. cultural advances
   C. scientific research
   D. biological evolution

16. The rise of agriculture led to the development of cities because

   A. man banded together for protection
   B. agriculture occurred mainly in river valleys so populations accumulated there
   C. more people were needed to help with the caring of plants and animals
   D. man seeks out companionship

The next 8 items refer to the following graph of human population growth. The solid-line section of the curve is based on actual data. The dashed-line sections are based on reasonable predictions.



17. What may have been responsible for the increase in population between 3000 and 2000 B.C.?

    A. Control of insects
    B. Increased grain production
    C. Discovery of pasteurization
    D. Discovery of vitamin sources

18. The rapid increase in world population in the 17th and 18th centuries was due to a(n)

    A. increase in the natality
    B. increase in the mortality
    C. decrease in food supply
    D. decrease in the natality

19. A large part of the increase in world population in the 20th century has been due to the

    A. decrease in natality
    B. increase in natality
    C. decrease in mortality
    D. increase in mortality

The next 5 items also refer to the graph of human population growth. Use the following key.

KEY: A. Factor probably responsible for the population growth rate between 0 and 1800 A.D.
B. Factor partially responsible for the present growth rate.
C. Possible outcome of the present growth rate.
D. Unlikely outcome of the present growth rate.

20. Elimination of predators of humans.

21. More space for recreational use.

22. Exceeding the food supply and possible famine.

23. Production of an infinite food supply.

24. Use of mechanical tools for agriculture.

25. Use of objects as tools

A. requires hand-eye coordination
B. is common among most land animals
C. does not require hands that can grip
D. requires a large, complex brain

26. The use of fire had its most significant effect on man by

A. allowing him to live in different geographic regions
B. protecting him from animals at night
C. giving him a wider variety of food
D. keeping him healthier

27. In early human societies

A. roles were genetically determined
B. division of labor occurred
C. communication was not important
D. all members were farmers

28. The present ecological problems of humans have been brought about by

A. biological evolution
B. natural irregularities in different cycles
C. cultural evolution
D. failure to adapt to the environment

29. Which of the following would provide an increasingly large human population with more available energy?

    A. increasing the number of herbivores
    B. increasing the number of carnivores
    C. reducing the variety of consumers
    D. reducing the variety of producers

30. Potential waste products can be turned into resources for technology. Which of the following is the best example of this?

    A. Fluoridation of water to prevent tooth decay
    B. Recycling of aluminum cans and bottles
    C. Application of synthetic fertilizers to soil
    D. Use of weed killers on road and railroad beds

31. Development of agriculture

    A. permitted early humans to establish permanent homes
    B. did not affect world population
    C. increased the competition for food by humans
    D. restricted the range of habitats for humans

32. Which of the following is a characteristic present in humans but lacking in other species? Humans can

    A. adapt to the environment
    B. interact with other members of the species
    C. pass on knowledge to next generations
    D. be aware and respond to surroundings

33. Technology differs from science chiefly in that

    A. its immediate aims are practical
    B. it makes less use of hypotheses
    C. it does not involve controlled experimentation
    D. it requires less intelligence

34. Society has, at times, slowed down technological and scientific advances by

    A. refusing to use harmful chemical substances
    B. refusing to buy things that are new and improved
    C. refusing to use weapons that are more deadly than those of the enemy
    D. refusing financial support for a project

35. The scientists of today can work on more complex problems than the scientists of the past mainly because they

    A. work much harder than earlier scientists
    B. have more ideas than earlier scientists
    C. build on the work of earlier scientists
    D. are more clever than earlier scientists

36. The development of agriculture provided a source of food resulting with

    A. people who were not farmers pursuing leisure activities
    B. increased scientific research aimed at seeking other sources of food
    C. an increase in the amount of barbarians stealing food
    D. a greater variety of services being provided by those who were not farmers

37. Science processes can lead to technological advances which aid society by

    A. making man more intelligent
    B. making man more comfortable
    C. causing pollution
    D. giving man nuclear power

38. Man's intellectual activities probably began as a result of

    A. the invention of the printing press
    B. the accumulation of abstract ideas
    C. advances in agriculture which insured a supply of food
    D. the increase in compulsory education

39. Methods of agriculture used by humans have created serious insect problems, primarily because these methods

    A. increase soil erosion
    B. provide concentrated areas of food for insects
    C. increase the effectiveness of insecticides over a long period of time
    D. grow crops in former "natural" areas

40. When each technological advance is publicized, society should

    A. determine if and how any bad side effects can be controlled
    B. make certain that it has no bad side effects
    C. reject the advance if it has any bad side effects
    D. make certain that the advantages of the advance are of great value

APPENDIX E

RESEARCH STUDY ACHIEVEMENT TEST ON SCIENCE, SOCIETY AND TECHNOLOGY

POST-TEST

SCIENCE/TECHNOLOGY/SOCIETY

NOTE: Some items in this test are related to material that is more advanced than the information presented or discussed during class. Make an effort to use ideas and information from discussions on this topic to select your answers.

Directions

- Use an ordinary HB pencil only.
- Fill in any further information on the left portion of Side 1 of your answer sheet as directed by your instructor.
- Read each item carefully and decide which of the alternatives BEST completes the statement, or answers the question. Locate that item number on the answer sheet and fill in the space that corresponds to the alternative that you have chosen.
- Mark your answers according to the instructions and the illustration given on Side 2 of the answer sheet. Avoid placing any marks among the black timing lines along the bottom margin of the answer sheet.
- Mark only one answer for each item. If you wish to change an answer, be sure that your original choice has been completely erased.
- Do not fold or bend the answer sheet.
- Return complete TEST BOOKLET and ANSWER SHEET at the end of the test period.

51. Technology is best defined as

A. the mother of science
B. processes of science
C. using aids for doing things
D. a source of answers to societal needs

52. The taming of fire had a direct influence on all of the following EXCEPT

A. man's struggle against predators
B. man's survival at greater altitudes
C. the diet that man could have
D. the development of cities

53. Initially, the taming of fire resulted with man

A. controlling part of his environment and fitting it to his needs
B. beginning to constantly improve his environment
C. becoming exposed to a greater variety of bacteria in different foods
D. becoming exposed to greatly increased levels of pollution

54. Man could live in permanent villages only after he could be sure of

A. a continued food supply
B. a constant climate
C. protection against invaders
D. good soil for growing food

55. Probably the first people, before agriculture developed, to live in permanent villages were

A. hunters
B. barbarians
C. herdsmen
D. fishermen

56. Scientific ideas are general ideas that

A. are used as sources of fact
B. enable the prediction of new facts and relationships
C. are known as predictions
D. have been proved conclusively and remain unchanged

57. The ability of humans to make and use tools depends upon their

A. upright posture and intelligence
B. taming of fire and intelligence
C. taming of fire, hand-eye coordination and intelligence
D. hand-eye coordination, upright posture and intelligence

58. Technological advances have produced changes in man's way of

    A. studying his environment
    B. adapting to any changes
    C. living
    D. testing knowledge

59. Which of the following technological advances could have the worst effect on society and the environment?

    A. The development of an underwater oil rig
    B. The development of a solar energy car
    C. The development of a computerized transit system
    D. The development of a laser powered surgical tool

60. Which of the situations is <u>most</u> <u>unlikely</u> to occur in the future?

    A. increasing population
    B. decreasing pollution
    C. increasing communication
    D. decreasing computerization

61. As man tamed fire, smoke caused him to

    A. use fires only outside his dwellings
    B. develop methods for removing smoke
    C. use mainly dry wood which gave off little smoke
    D. control his use of fire

62. Greatest advances in technology in the future will most likely occur with

    A. computers, energy, communications
    B. pollution control, government, transportation
    C. government, energy, computers
    D. waste management, climate control, medicine

63. Early agriculture

    A. resulted with a stable population
    B. caused man to hunt only for meat
    C. resulted in some large famines
    D. developed in Southern Africa

64. The most basic and important technological advance was

    A. the domestication of plants
    B. the domestication of animals
    C. the use of rocks and bones as tools
    D. the ability to employ fire

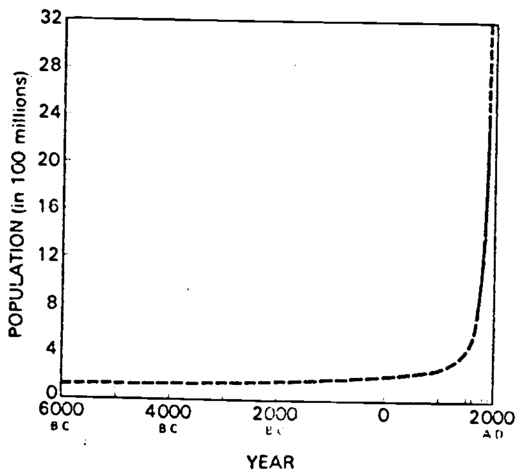
65. The use of fire has had the least direct influence on

    A. technological advances
    B. cultural advances
    C. scientific research
    D. biological evolution

66. The rise of agriculture led to the development of cities because

    A. farmers wanted to live close together
    B. agriculture occurred mainly in river valleys so populations accumulated there
    C. more people were needed to help with the caring of plants and animals
    D. politics could develop more quickly in cities

The next 8 items refer to the following graph of human population growth. The solid-line section of the curve is based on actual data. The dashed-line sections are based on reasonable predictions.



67. What may have been responsible for the increase in population between 3000 and 2000 B.C.?

    A. Control of insects
    B. Increased grain production
    C. Discovery of pasteurization
    D. Discovery of vitamin sources

68. The rapid increase in world population in the 17th and 18th centuries was due to an increase in

    A. natality
    B. mortality
    C. food supply
    D. immigration

69. A large part of the increase in world population in the 20th century has been due to the

    A. decrease in natality
    B. increase in natality
    C. decrease in mortality
    D. increase in mortality

The next 5 items also refer to the graph of human population growth. Use the follow key.

KEY: A. Factor probably responsible for the population growth rate between 0 and 1800 A.D.
B. Factor partially responsible for the present growth rate.
C. Possible outcome of the present growth rate.
D. Unlikely outcome of the present growth rate.

70. Elimination of predators of humans.

71. More space for recreational use.

72. Exceeding the food supply and possible famine.

73. Production of an infinite food supply.

74. Use of mechanical tools for agriculture.

75. Use of objects as tools

    A. requires hand-eye coordination
    B. is common among most land animals
    C. does not require hands that can grip
    D. requires high levels of intelligence

76. The use of fire had its most significant effect on man's population by

    A. allowing him to live in different geographic regions
    B. protecting him from animals at night
    C. giving him a wider variety of food
    D. keeping him healthier

77. In early human societies

    A. roles were genetically determined
    B. division of labor occurred
    C. science was not practiced
    D. all members were laborers

78. The present ecological problems of humans have been brought about by

    A. biological evolution
    B. different cycles in nature
    C. cultural changes
    D. his failure to adapt

79. Which of the following would provide an increasingly large human population with more available energy?

    A. increasing the number of herbivores
    B. increasing the number of carnivores
    C. reducing the variety of consumers
    D. reducing the variety of producers

80. Potential waste products can be turned into resources for technology. Which of the following is the best example of this?

    A. Fluoridation of water to prevent tooth decay
    B. Recycling of aluminum cans and bottles
    C. Application of synthetic fertilizers to soil
    D. Use of weed killers on road and railroad beds

81. Development of agriculture

    A. permitted early humans to establish permanent homes
    B. did not affect world population
    C. increased the competition for food by humans
    D. restricted the range of habitats for humans

82. Which of the following is a characteristic present in humans but lacking in other species? Humans can

    A. change more quickly
    B. interact with other members of the species
    C. pass on knowledge to next generations
    D. be aware and respond to surroundings

83. Technology differs from science chiefly in that

    A. its immediate aims are practical
    B. it makes less use of hypotheses
    C. it does not involve controlled experimentation
    D. it requires more intelligence

84. Society has, at times, slowed down technological and scientific advances by

A. refusing to use harmful chemical substances
B. refusing to buy things that are new and improved
C. refusing to use weapons that are more deadly than those of the enemy
D. refusing financial support for a project

85. Science is knowledge based on

A. thoughts of very intelligent men
B. textbooks written by professors
C. observed facts and tested truths
D. repeated experiments

86. The development of agriculture provided a source of food resulting with

A. people who were not farmers pursuing leisure activities
B. increased scientific research aimed at seeking other sources of food
C. an increase in the amount of barbarians stealing food
D. a greater variety of services being provided by those who were not farmers

87. Science processes can lead to technological advances which aid society by

A. making man more intelligent
B. making man more comfortable
C. reducing pollution
D. giving man nuclear power

88. Man's intellectual activities probably began as a result of

A. the invention of the printing press
B. increased modes of transportation
C. advances in agriculture which insured a supply of food
D. the increase in compulsory education

89. Methods of agriculture used by humans have created serious insect problems, primarily because these methods

A. increase soil erosion
B. provide concentrated areas of food for insects
C. increase the effectiveness of insecticides over a long period of time
D. grow crops in former "natural" areas

90. When each technological advance is publicized, society should

    A. determine if and how any bad side effects can be controlled
    B. make certain that it has no bad side effects
    C. reject the advance if it has any bad side effects
    D. make certain that the advantages of the advance are of great value

APPENDIX F

SAMPLE OF *ITEMANAL R198 PRINT-OUT FOR ITEMS FROM SCIENCE, SOCIETY AND TECHNOLOGY ACHIEVEMENT TEST

ITEM 36: DIF=0.533, RPB= 0.304, CRPB= 0.184 (95% CON= 0.059, 0.304)
RBIS= 0.381, CRBIS= 0.231, IRI=0.151

GROUP	N	INV	NF	OMIT	1	2	3	4*	5
TOTAL	240	0	0	0	0.05	0.40	0.02	0.53	0.0
HIGH	58	0			0.02	0.22	0.02	0.74	0.0
MID	108	0			0.05	0.40	0.02	0.54	0.0
LOW	74	0			0.07	0.54	0.03	0.36	0.0
TEST SCORE MEANS					21.82	22.26	23.40	24.80	0.0
DISCRIMINATING POWER					-0.05	-0.32	-0.01	0.38	0.0
STANDARD ERROR OF D.P.					0.01	0.02	0.00	0.02	0.0

ITEM 37: DIF=0.742, RPB= 0.239, CRPB= 0.134 (95% CON= 0.007, 0.256)
RBIS= 0.323, CRBIS= 0.181, IRI=0.104

GROUP	N	INV	NF	OMIT	1	2*	3	4	5
TOTAL	240	0	0	0	0.20	0.74	0.04	0.02	0.0
HIGH	58	0			0.09	0.90	0.02	0.0	0.0
MID	108	0			0.19	0.77	0.03	0.02	0.0
LOW	74	0			0.32	0.58	0.07	0.03	0.0
TEST SCORE MEANS					22.08	24.21	21.44	21.25	0.0
DISCRIMINATING POWER					-0.24	0.32	-0.05	-0.03	0.0
STANDARD ERROR OF D.P.					0.01	0.03	0.01	0.00	0.0

ITEM 38: DIF=0.646, RPB= 0.269, CRPB= 0.155 (95% CON= 0.028, 0.276)
RBIS= 0.346, CRBIS= 0.199, IRI=0.129

GROUP	N	INV	NF	OMIT	1	2	3*	4	5
TOTAL	240	1	0	1	0.07	0.07	0.65	0.22	0.0
HIGH	58	0			0.05	0.07	0.83	0.05	0.0
MID	108	1			0.06	0.06	0.64	0.23	0.0
LOW	74	0			0.08	0.08	0.51	0.32	0.0
TEST SCORE MEANS					23.13	21.69	24.45	21.92	0.0
DISCRIMINATING POWER					-0.03	-0.01	0.31	-0.27	0.0
STANDARD ERROR OF D.P.					0.01	0.01	0.02	0.01	0.0

ITEM 39: DIF=0.742, RPB= 0.243, CRPB= 0.138 (95% CON= 0.012, 0.260)
RBIS= 0.329, CRBIS= 0.187, IRI=0.106

GROUP	N	INV	NF	OMIT	1	2*	3	4	5
TOTAL	240	0	0	0	0.05	0.74	0.13	0.07	0.0
HIGH	58	0			0.05	0.86	0.02	0.07	0.0
MID	108	0			0.02	0.74	0.18	0.06	0.0
LOW	74	0			0.11	0.65	0.15	0.09	0.0
TEST SCORE MEANS					21.08	24.22	22.19	22.00	0.0
DISCRIMINATING POWER					-0.06	0.21	-0.13	-0.03	0.0
STANDARD ERROR OF D.P.					0.01	0.03	0.01	0.01	0.0

ITEM 40: DIF=0.537, RPB= 0.335, CRPB= 0.215 (95% CON= 0.091, 0.333)
RBIS= 0.420, CRBIS= 0.270, IRI=0.167

GROUP	N	INV	NF	OMIT	1*	2	3	4	5
TOTAL	240	5	5	0	0.54	0.10	0.07	0.27	0.0
HIGH	58	1			0.81	0.02	0.02	0.14	0.0
MID	108	2			0.50	0.14	0.07	0.27	0.0
LOW	74	2			0.38	0.11	0.12	0.36	0.0
TEST SCORE MEANS					24.91	22.46	21.17	22.23	0.0
DISCRIMINATING POWER					0.43	-0.09	-0.10	-0.23	0.0
STANDARD ERROR OF D.P.					0.02	0.01	0.01	0.02	0.0

APPENDIX G

PILOT STUDY STUDENT APPRAISAL OF STUDENT TEACHER QUESTIONNAIRE

DO NOT PUT YOUR NAME ON THIS PAPER

Student Appraisal of Science-Society-Technology Lessons

- THE FOLLOWING QUESTIONS WILL BE USED TO HELP YOUR STUDENT TEACHER DO A BETTER JOB.
- THEY WILL NOT BE USED TO GRADE HIM OR HER.
- WHAT YOU SAY IS PRIVATE, NO ONE WILL KNOW WHAT YOUR PERSONAL ANSWERS ARE.
- YOUR ANSWERS SHOULD TELL WHAT YOU THINK ABOUT YOUR STUDENT TEACHER.
- USE THE FOLLOWING WORDS TO DESCRIBE THE SENTENCES BELOW. PICK THE BEST WORD FOR EACH SENTENCE AND CIRCLE ITS NUMBER.

1	2	3	4	5
ALWAYS (As Much as Possible)	OFTEN	SOMETIMES	RARELY	NEVER

1	2	3	4	5	1.	The student teacher seemed to be friendly.
1	2	3	4	5	2.	The student teacher asked questions that tested our memory.
1	2	3	4	5	3.	I was interested in the lesson.
1	2	3	4	5	4.	The student teacher asked questions that made me think.
1	2	3	4	5	5.	The student teacher explained the lessons clearly.
1	2	3	4	5	6.	I did not have enough time to think of answers to the questions asked.
1	2	3	4	5	7.	The student teacher enjoyed teaching our class.
1	2	3	4	5	8.	The questions asked helped me learn.
1	2	3	4	5	9.	I did not understand what the student teacher was talking about.
1	2	3	4	5	10.	I was afraid to try and answer the student teacher's questions.
1	2	3	4	5	11.	The student teacher listened carefully to our answers.
1	2	3	4	5	12.	The student teacher helped us reason out answers to difficult questions.
1	2	3	4	5	13.	The student teacher used our answers in the discussion.
1	2	3	4	5	14.	I was free to disagree with the student teacher.
1	2	3	4	5	15.	The student teacher gave everyone a chance to answer questions.
1	2	3	4	5	16.	The student teacher clearly explained what was planned.
1	2	3	4	5	17.	The student teacher "picked on" some people in our class.
1	2	3	4	5	18.	The student teacher encouraged everyone to ask questions.
1	2	3	4	5	19.	The student teacher criticized our answers to his/her questions.
1	2	3	4	5	20.	The student teacher was enthusiastic.
1	2	3	4	5	21.	The student teacher made good use of the class time.
1	2	3	4	5	22.	The test was fair.
1	2	3	4	5	23.	The student teacher clearly explained how he/she would teach.
1	2	3	4	5	24.	The student teacher was well prepared for the lesson.
1	2	3	4	5	25.	I learned a lot during the lesson.

APPENDIX H

RESEARCH STUDY STUDENT APPRAISAL OF STUDENT TEACHER QUESTIONNAIRE

DO NOT PUT YOUR NAME ON THIS PAPER

Student Appraisal of Science-Society-Technology Lessons

- THE FOLLOWING QUESTIONS WILL BE USED TO HELP YOUR STUDENT TEACHER DO A BETTER JOB.
- THEY WILL NOT BE USED TO GRADE HIM OR HER.
- WHAT YOU SAY IS PRIVATE, NO ONE WILL KNOW WHAT YOUR PERSONAL ANSWERS ARE.
- YOUR ANSWERS SHOULD TELL WHAT YOU THINK ABOUT YOUR STUDENT TEACHER.
- USE THE FOLLOWING WORDS TO DESCRIBE THE SENTENCES BELOW. PICK THE BEST WORD FOR EACH SENTENCE AND CIRCLE ITS NUMBER.
- TRANSFER YOUR ANSWERS TO SIDE 2, ITEMS 101-120 OF YOUR ANSWER SHEET.

1	2	3	4	5
ALWAYS (As Much as Possible)	OFTEN	SOMETIMES	RARELY	NEVER

1 2 3 4 5 101. The student teacher seemed to be friendly.

1 2 3 4 5 102. The student teacher asked questions about things we already knew.

1 2 3 4 5 103. I was interested in the lesson.

1 2 3 4 5 104. The student teacher asked questions that made me think.

1 2 3 4 5 105. The student teacher explained the lessons clearly.

1 2 3 4 5 106. The student teacher enjoyed teaching our class.

1 2 3 4 5 107. The questions asked helped me learn.

1 2 3 4 5 108. The student teacher listened carefully to our answers.

1 2 3 4 5 109. The student teacher helped us reason out answers to difficult questions.

1 2 3 4 5 110. The student teacher used our answers in the discussion.

1 2 3 4 5 111. I was free to disagree with the student teacher.

1 2 3 4 5 112. The student teacher gave everyone a chance to answer questions.

1 2 3 4 5 113. The student teacher clearly explained what was planned.

1 2 3 4 5 114. The student teacher encouraged everyone to ask questions.

1 2 3 4 5 115. The student teacher was enthusiastic.

1 2 3 4 5 116. The student teacher made good use of the class time.

1 2 3 4 5 117. The test was fair.

1 2 3 4 5 118. The student teacher clearly explained how he/she would use questions to teach this unit.

1 2 3 4 5 119. The student teacher was well prepared for the lesson.

1 2 3 4 5 120. I learned a lot during the lesson.

APPENDIX I

QUESTIONS FOR CLASSIFYING ACCORDING TO THE QUESTION CATEGORY SYSTEM FOR SCIENCE

Classify each of the following questions according to Blosser's categorization (see attached).

Use the following key A) Cognitive Memory
B) Convergent Thinking
C) Divergent Thinking
D) Evaluative Thinking

1) What is the general name for a disease carrier? ______

2) Why should Canada join the efforts toward space exploration? ______

3) What do you think might happen if the solution were made more acidic? ______

4) What is the proper way to store sodium? ______

5) Is the conclusion you reached based on valid evidence? ______

6) What does "semipermeable" mean? ______

7) What generalizations can you make from the data? ______

8) How can you explain what happened when these two were mixed? ______

9) Which of these is a Florence flask? ______

10) What do these data mean? ______

11) Which of these experimental procedures would serve best to determine the effectiveness of inoculating sheep against anthrax? ______

12) What is an example of a conifer? ______

13) What would be the most probable source of error in this experiment? ______

14) Why is it necessary to collect data accurately? ______

15) What does D.N.A. stand for? ______

16) What are some other questions that were answered by the experiment? ______

17) Why did you use litmus paper rather than hydrion paper? ______

18) On what is the modern classification of higher plants based? ______

19) What new question is raised by this investigation? ______

20) Which class of plants has the greatest diversity? ______

21. What inferences can you make based on the data you collected? ______

22. If both parents were hybrids, what would you expect the F_1 generalization to look like? ______

23. When were viruses discovered? ______

24. Can you suggest a design for an experiment to investigate that? ______

25. What is the definition for osmosis? ______

26. What do you think life on Earth will be like 200 years from now? ______

27. Explain why it is or is not correct to say that matter is not destroyed when wood is burned? ______

28. What is a disease causing organism called? ______

29. How would you handle this situation? ______

30. What happened to the air inside the balloon, in terms of molecular motion, when the flask was heated? ______

APPENDIX J

QUESTION CATEGORY SYSTEM FOR SCIENCE

<table>
<tr><th colspan="3">QUESTION CATEGORY SYSTEM FOR SCIENCE</th></tr>
<tr><th>Level I</th><th>Level II</th><th>Level III</th></tr>
<tr><td rowspan="2">I. CLOSED QUESTIONS
(limited number of acceptable responses)</td><td>A. COGNITIVE MEMORY*</td><td>1. RECALL: includes repeat, duplicate, memorized definitions
2. IDENTIFY or NAME or OBSERVE</td></tr>
<tr><td>B. CONVERGENT THINKING*</td><td>1. ASSOCIATE and/or DISCRIMINATE; CLASSIFY
2. REFORMULATE
3. APPLY: previously acquired information to solution of new and/or different problem
4. SYNTHESIZE
5. CLOSED PREDICTION: limitations imposed by conditions or evidence
6. MAKE "CRITICAL" JUDGMENT: using standards commonly known by class</td></tr>
<tr><td rowspan="2">II. OPEN QUESTIONS
(greater number of acceptable responses)</td><td>C. DIVERGENT THINKING*</td><td>1. GIVE OPINION
2. OPEN PREDICTION: data insufficient to limit response
3. INFER or IMPLY</td></tr>
<tr><td>D. EVALUATIVE THINKING*</td><td>1. JUSTIFY: behavior, plan of action, position taken
2. DESIGN: new method(s), formulate hypotheses, conclusion(s)
3. JUDGE A: matters of value, linked with affective behaviors
4. JUDGE B: linked with cognitive behaviors</td></tr>
<tr><td>III. MANAGERIAL</td><td colspan="2">Teacher uses to facilitate classroom operations, discussion</td></tr>
<tr><td>IV. RHETORICAL</td><td colspan="2">Teacher uses to reinforce a point; does not expect (or want) a response</td></tr>
</table>

*1. *Cognitive-Memory:* evidence understood to be directly available (textbook, previous lesson or discussion, film, filmstrip, chart, experiment, field trip, etc.)
2. *Convergent Thinking:* evidence directly available but not in the form called for by question
3. *Divergent Thinking:* evidence for response not directly available
4. *Evaluative Thinking:* evidence may or may not be directly available; criteria for responding available, directly or indirectly. Implication that student may be called upon to provide a defense for his response.

APPENDIX K

EXAMPLES OF QUESTIONS FOR DIFFERENT CATEGORIES OF THE QUESTION CATEGORY SYSTEM FOR SCIENCE

EXAMPLES OF QUESTIONS

The following pages contain some examples of the various kinds of questions that might be classified under the different thinking operations listed in the Question Category System.

It is difficult to take a question out of the context of the planned lesson and classroom discussion and arbitrarily write it out as an example of a particular thinking operation. Some of the examples cited might be categorized under different thinking operations if they were used in a different context. These questions are given to be used as general guides in learning to distinguish the place in the Question Category System into which a given question might be classified.

It might be a good idea to attempt to write several questions of your own for each thinking operation listed in the Question Category System. Or, you might list all of the questions you could possibly ask in developing a specific lesson or topic and then classify each to see how many different thinking operations you are attempting to stimulate in your students.

EXAMPLES OF QUESTIONS RELATING TO DIFFERENT TYPES OF THINKING OPERATIONS

A. COGNITIVE-MEMORY QUESTIONS (evidence for answer directly available in some form)

1. *RECALL:* student is asked to remember and present information previously learned. This may include asking student to repeat or restate a response made earlier in the discussion. Student may also be asked to perform some manual operation that has been explained or to duplicate it as specified in the directions.
   "What is the function of the blood?"
   "What is the definition of osmosis?"
   "What did you tell us a few minutes ago about that?"
   "What is the proper way to focus a microscope?"

2. *IDENTIFY, NAME, OBSERVE:* student is asked to identify an object by naming it, pointing to it, selecting it out of a group; to state what he observed without drawing any inferences, conclusions, etc.
   "Which flask shown in the picture is the Florence flask?"
   "Give me an example of an igneous rock."
   "When the copper was heated, what color was the flame?"
   "How many different cell layers do you see on that slide?"

B. CONVERGENT THINKING QUESTIONS (evidence for response directly available but not in form called for by question)

1. *ASSOCIATE, DISCRIMINATE, CLASSIFY:* student is asked to focus on likenesses or similarities; to equate; or student is asked to compare or contrast, to focus on differences. CLASSIFY (criteria given) is also placed in this category since it involves association and discrimination.

Student is given a set of criteria or helped to develop a set and then use this in classifying objects.
"Why are sandstone, limestone and conglomerate all classed as sedimentary rocks?"
"What are some common properties of plants and animals?"
"What're the major differences between DNA and RNA--they're both nucleic acids?"
"How can you distinguish gneiss from schist?"
"Limestone and sandstone are both sedimentary rocks. How can you tell them apart?"
"Group the materials listed on the board as elements, compounds, or mixtures."

2. *REFORMULATE:* student is asked to give the answer in *his own* words, not those of the textbook or teacher; to interpret verbal data into graphical form or vice versa; to paraphrase an important idea.
"What is your version of the results shown in the chart on page 45?"
"Can you tell us, in your own words, what these data mean?"

3. *APPLY:* student is asked to use previously acquired data in stating the possible causes of a phenomenon, the reasons for a particular procedure or process--providing this goes beyond a memorized definition available in the textbook or previous lesson material (if this is all that is involved the question is a "recall" one). Student may also be asked to use previously acquired knowledge in solving a similar but unfamiliar problem; to cite examples to illustrate a particular phenomenon or process other than those already discussed; or student is given a value, skill or definition and asked to identify or compose an example of its use.
"...and this process is called osmosis. Where might osmosis take place in our bodies?"
"What happened to the air inside the balloon, in terms of molecular motion, when the flask was heated?"
"What caused the limestone to effervesce when acid was dropped on it?"
"Based on what you have just said about the process of convection, what part do you think convection currents play in the heating and cooling of houses?"

4. *SYNTHESIZE:* student is asked to combine pieces of information to form a whole, to make generalizations.
"If the air temperature in a room is 85°F and the wall temperature is 50°F, why might a person feel cold?"
"Explain why it is or is not correct to say that matter is not destroyed when a piece of wood is burned."
"What generalization can you make from the data you gathered?"

5. *CLOSED PREDICTION:* student is asked to form a prediction, using data which limits his answer.

"On the basis of the results we collected in this class, how do you think arm lengths would vary if we were to use younger students in our sample?"
"If both parents were hybrids, what would you expect the F_1 generation to look like?"

6. *MAKE "CRITICAL" JUDGMENT:* student is asked to form a restrictive judgment about the correctness, adequacy, appropriateness, etc. of some situation or response, using standards or criteria that are commonly known by the class.
"Does anyone wish to challenge that answer?"
"How do the relative sizes of these objects compare?"
"Is that the proper procedure to use?"

C. DIVERGENT THINKING QUESTIONS (evidence for response not directly available)

1. *GIVE OPINION:* student is asked for his opinion *without* also being asked to justify it or to present a rationale for his response. These differ from the "make 'critical' judgment" variety in that the context in which the question is asked is such that there is *no* implication that only a limited number of responses will be considered acceptable by the teacher.
"Do you think we should repeat this experiment?"
"What do you think?"
"Do you think the results we got would be changed much if we were to increase the temperature two degrees?"

2. *OPEN PREDICTION:* student is asked to make a prediction *but* the data available are insufficient to limit the response expected; students are asked to speculate, to "brain-storm."
"If we were to land a spaceship on Venus and, if Venus were to be inhabited, what might the welcoming committee look like?"
"What do you think might happen if the Sun were to 'die'?"
"What do you think life on Earth will be like 200 years from now?"

3. *INFER or IMPLY:* student is asked to draw inferences or to point out implications.
"What can you infer, from the evidence you collected in your experiment, about the growth curve of those bacteria?"
"What inferences can you make based on the data you collected?"
"What are the implications of that conclusion?"

D. EVALUATIVE THINKING QUESTIONS (evidence for response may or may not be directly available; criteria for responding are available, either directly or indirectly. Implication is that student may be called upon to provide a defense for his response.)

1. *JUSTIFY:* student is asked to elaborate on the reasons for his response; to defend his position on some rational grounds; to develop a rationale for his actions.
   "Why did you use litmus paper rather than hydrion paper?"
   "Upon what basis did you form this conclusion?"

2. *DESIGN:* student is asked to design or formulate a new method of doing something, to establish a testable hypothesis, etc.
   "Can you think of a different way of solving this problem?"
   "Can you suggest a design for an experiment to investigate that?"

3. *JUDGE A:* student is asked to judge some situation involving a matter of value or worth, with the implication that the thing being judged relates to himself or other persons, hence the involvement of affective behavior.
   "Should we set up a policy whereby human organs are automatically made available for transplant operations when a person dies?"
   "How would you handle this situation?"

4. *JUDGE B:* student is asked to judge some situation in which the judgment is to be made on the basis of utility, consistency, logical accuracy or other cognitive standard.
   "Which process should we use if we wish to solve the problem in the most efficient manner?"
   "Is the conclusion you reached based on valid evidence?"

APPENDIX L

SAMPLE OF CATEGORIZED QUESTIONS FROM TREATMENT LESSONS

Category	Questions
Recall	What are some example of technologies that you have already used today?
H.C.L.	Now, keeping all those examples in mind, what would be a good definition of 'technology'?
H.C.L.	3. What do you think might have been some problems associated with using fire for those cavemen?
H.C.L.	4. What might be some ways that they could solve that problem?
H.C.L.	5. What would have been some consequences of early man's discovery of agriculture?
H.C.L.	6. How would that problem lead to the further development of technology?
H.C.L.	7. Why might they want to improve any tool that already does the job for them?
H.C.L.	8. How would they go about improving it?
H.C.L.	9. How might the discovery of agriculture affect the whole community?
H.C.L.	10. What might they do with that increased leisure time?
H.C.L.	11. What kinds of occupations?
H.C.L.	12. Why do you think that there might be more thieves?
H.C.L.	13. Why do you disagree?

APPENDIX M

PILOT STUDY INSTRUCTIONAL UNIT OUTLINE

SCIENCE, SOCIETY, AND TECHNOLOGY

(Reference: Chapter 1, Asimov, Science Past-Science Future)

General Objective

To identify the interrelationships among science, society and technology.

Main Concepts to be Developed

1. Technology is man's (society's) way of doing desirable things more easily, by means of something that is not a part of him;
2. Science processes are used in the discovery of technologies;
3. Science processes are sometimes stimulated by technologies;
4. Technology has positive and negative effects on society;
5. The negative effects technology has on society may only be solved by further advances in technology.

Specific Behavioral Objectives

As a result of this unit of study, the student will be able to:

a. define technology, as opposed to science, as is used by man.

b. describe the uses of fire

c. describe the consequences of man developing the use of fire;

d. identify and explain the uses of fire as a functioning of the processes of science;

e. illustrate (describe) the dependency that man has developed for fire;

f. justify the statement; "Problems of a present technology may only be alleviated through further advances in technology;

g. cite and describe agriculture as a result of major technological advances;

h. identify and explain the discovery of agriculture as a means of the functioning of the processes of science;

i. describe the consequences of man's use of agriculture (positive and negative).

j. explain the dependency that man has developed for agriculture;

k. explain how continued technological advances in agriculture were a part of man's cultural history;

l. evaluate the effects of science and major technological advances on society, science and technology.

Note: Prior to the teaching of the lesson, some introductory statement should:

1. identify plans to study (investigate) the interrelationships (interdependencies) of science, society and technology;

2. indicate the length of the unit (ie. two 30 to 40 minute sessions followed by a 30 to 40 minute test);

3. indicate that for the most part the teacher will be using questions to focus the students' thoughts about some aspects of technology, science and society as well as their interrelationships.

The Lesson Plan

Before we attempt to define technology, maybe we can consider some examples. Let's list some on the board.

1. What would be some simple technological advances? (pause) - Name! (If necessary remind class of questioning technique or procedures to be used). Probe for simple examples, stone vs. hammer as a nutcracker, etc. (after the listing of some examples of technological advances).

2. What is a definition for technology?

   - Guesses will be made by students and further examples cited.

   - A polished definition should be derived from the guesses and examples: "Technology is an 'aid' for doing things which are not part of your own body."

3. Who uses technology?

   - Discussion should develop the idea that mainly man applies technology - but other animals do as well, eg., birds -- dropping nuts, clams on stones, hanging their prey on trees or fences; insects -- spiders (attach web to surfaces), etc. (various probes can be prepared).

   - A supplementary question may be asked so that students have an appreciation of how long technology has existed: "When did man start using technology?" "What might be some of man's earliest technologies?"

4. Why did man start using technology? OR Why do you use technology?

   - Student should understand that technology is applied to make things easier.

Note: At this point concept 1 should be written on the board, ie., "Technology is man's (society's way of doing something desirable more easily by means of something other than a part of his body."

5. What do you think was the first important tool discovered by man that has had an effect on man's life over the entire world ever since? (Probes and supplementary questions will probably be needed since students will likely not immediately consider fire).

   Some probes might include:

   - What tool allows man to live anywhere?

   - What does man need for survival

   - etc.

6. How do you think man discovered fire?

   - This question would hopefully provide students with the opportunity to formulate their own answer from their own experiences.

   Supplementary questions may include:

   - "Does fire exist naturally?" ...

   - ... "In what form(s)?"

   - "How do fires start naturally?"

7. What do you think would be meant by "Man gradually learned how to tame fire?"

   - The student will see that man in his discovery and use of fire had to learn simple laws about fire; eg., fire grew if it was fed, fire could be started in various ways, it went out when not fed or if doused with water.

   - The student should also see that the simple laws man learned about fire were learned as a result of man's application of various processes of science. Probing questions would include: "How did man learn these things about fire?"

   Science (defined by Gage Dictionary). "The beginnings of a knowledge of facts and laws arranged in an orderly system."

   - At this point, concept 2 should be summarized on chalkboard.

8. What are some of the more common uses man has found for fire?

   - Some uses may have already been presented during probes for question #5.

   - The most obvious uses will be mentioned immediately. The less apparent uses can be desired through probing. The uses should include: heat, light, cooking, protection.

9. How did (does) man use fire to shape his environment to suit his needs? OR How did man's ability to use fire affect his life (existence)?

   - This question is used so that students can see some of the consequences of man's use of fire. For example, man's cooking of food means not only that he could eat many more types of food, but subsequently his range and numbers increase because of increased food supply. Fire killed bacteria in food - less illness. Heating food begins its physical breakdown (digestion). (Certainly probing can be used to advantage here.)

10. A number of facts were learned in association with the use of fire. How do you think man would learn these facts (refer to answers (discussions) in last question)?

   - Students may be directed to previous definition of science and associated processes of science.

   - The aim is to indicate (identify) some interrelationship between science and technology. That is, technological advance stimulates science and science in turn stimulates further advances in technology. eg., science processes discovery of fire further science processes used of fire etc.

Concept 3 can be summarized on chalkboard as summary of questions 8, 9 and 10.

11. What would happen to man if there was no fire? (Associated questions for clarification may include: where would man have to live? What would he have to eat? What would happen to the human population?)

    - This question would identify the dependency man developed for fire (technological advance).

    - Some students may suggest that man could go back to a more primitive state of not using fire and thus survive. Associated ideas would further support the fact that fire enables man to migrate to cooler climates and increase population through increased food supply. If fire disappeared from the "societies" of prehistoric man, we would expect those societies to suffer or perish. Those societies which advanced in technology and learned how to make and control fire, survived.

12. How does man solve the problems created by a technology?

    - The answer (further advances in technology) may have already been reached during discussions associated with question 11.

    - The student should realize that society's dependency on technology and technological advances is continuous.

Concept 4 can be given in summary. (Technology has both positive and negative effects on society).

13. Associated with man's survival and his use of fire what is another important technological advance?

    - Probes similar to those used with question 5 will be required to elicit "agriculture" as the desired response.

14. How do you think man may have discovered agriculture? (Again development of discussion will require probes similar to those used during question 6 and 7).

    - The main point to be reached is that science (a knowledge of facts and laws arranged in an orderly system) was responsible for the technological advances associated with agriculture.

    - A leading question might be: "Did man discover agriculture through luck? What processes would be used?"

15. What might be some consequences of man's discovery and use of agriculture?

    - positive and negative aspects may be probed.

eg., - more food produced on a given piece of land.

- more people could be supported by a given piece of land.

- fewer people required for food production.

- others could be involved in other things than food production such as art, literature, medicine, law, etc. and thus intellectualization of man could occur.

- increased population.

- formation of cities and city states.

- development of pesticides, herbicides, etc.

- resultant pollutants.

- hardier crops.

- hardier insect pests etc.

(Only time will limit the extent of the discussion and probing associated with this question).

16. What would be the consequences if a drought, flood or plague of locusts occurred?

    - The student is to realize the dependency that man develops for agriculture.

    - The answer to this question parallels the answer to question 11. The technological advances of man are potentially catastrophic. At this point concept 3 and 4 have been fully developed. Students should see how these concepts apply to a riculture as well as fire.

17. How could man prevent the floods, droughts and plagues of locusts which could destroy his crops?

    - The student is to be led to the realization that the only solution brought about by technology is the further advancement of technology. The question may be rephrased to "How do we prevent such catastrophes at present?"

    - At this point, students should realize that concept 5 can be applied to agriculture as well as fire.

18. A technological advance of the past, present or future can be elicited from a student and written on the board. The students and teacher should then apply each of the five concepts to the technological advance and draw conclusions as to the effect it had on science, technology and society. Conversely, the effects that science, technology and society had on the technological advance must also be examined. The following can serve as an example:

Technological Advance - internal combustion engine.

Concept 1 - Technology is man's way of doing something desirable more easily by means of something other than a part of his body. This concept is very applicable, the internal combustion engine is a convenient tool capable of doing the work of many men or animals (horses). Students can provide infinite examples.

Concept 2 - Science is involved in the discovery of technology. Science was undoubtedly used in the invention of the internal combustion engine. A knowledge of the physical laws of combustible substances is just one aspect of science involved in its invention. Students may be asked to supply others.

Concept 3 - Science is stimulated by technology. The invention of the internal combustion engine resulted in an explosion of technology and science in all those areas in which the internal combustion engine is related or used. For example, it now became possible for man to fly. Increased knowledge of the physical laws of aerodynamics developed as well as a concentration of technology in the area of the newly developed aircraft. Technology stimulated science and science in turn develops new ideas for tools for man's use. Can the students think of other examples in which science and technology and interrelated.

Concept 4 - Technology has positive and negative effects on society. (Students should be able to list various positive and negative effects with some direction by probing questions).

Concept 5 - The negative effects technology has on society may only be solved by further advances in technology.

The problems of the internal combustion engine has caused efforts to produce more efficient engines and to look at other sources of energy developing new means of transportation. The students can be asked to provide other examples where advances in a technology are alleviating the problems associated with that technology. The teacher should be prepared to provide some suggestions.

eg., use of recombinant DNA to produce insulin, possible other enzymes which may increase the population of diabetics because they will survive longer and produce more offspring with the hereditary disease.

Other technologies may be analyzed in the same way if time allows.

APPENDIX N

RESEARCH STUDY INSTRUCTIONAL UNIT OUTLINE

Science, Society, and Technology

(Reference Chapter 1, Asimov, Science Past - Science Future)

General Objective:

To identify the interrelationships among science, society and technology.

Main Concepts to be Developed:

1. There are many complex interdependencies and interrelationships among science, technology and society.

2. Technology is man's (society's) way of doing something desirable more easily by using things which are not part of his body.

3. The negative effects that technology has on society may only be solved by further advances in technology.

Some Behavioral Objectives

As a result of these classes, the student will be able to:

a) define technology

b) describe various positive and negative effects that technological advances have on society (past, present or future).

   eg. effects of the discoveries of fire and agriculture on society and societal (cultural) evolution.

c) describe societal (cultural) evolution in relation to technological advances and subsequent societal (cultural) evolution.

d) define science

e) describe man's discoveries and uses of technologies in terms of:

   i) his traits
   ii) societal needs

f) interpret the statement: "Problems of a technology may be alleviated through further advances in the technology".

g) interpret, analyze and predict the effects of a major technological advance on society, science and technology (past, present or future).

APPENDIX O

LINEAR DISCRIMINANT FUNCTION TABLES FOR STUDENT APPRAISAL OF STUDENT TEACHERS QUESTIONNAIRE ITEMS RELATED TO TEACHING AND QUESTIONING EFFECTIVENESS

TABLE XXXII

SUMMARY OF LINEAR DISCRIMINANT FUNCTIONS FOR STUDENT APPRAISAL OF STUDENT TEACHERS QUESTIONNAIRE ITEMS RELATED TO TEACHING AND QUESTIONNING EFFECTIVENESS

a. Item 101

SOURCE	SS	MS	Df	F	P
Treatment	0.016	0.016	1	0.047	0.829
Within	80.715	0.339	238		

b. Item 102

SOURCE	SS	MS	Df	F	P
Treatment	0.265	0.265	1	0.502	0.479
Within	125.982	0.529	238		

c. Item 103

SOURCE	SS	MS	Df	F	P
Treatment	0.337	0.337	1	0.329	0.567
Within	243.455	1.023	238		

d. Item 104

SOURCE	SS	MS	Df	F	P
Treatment	0.067	0.067	1	0.113	0.737
Within	140.530	0.590	238		

e. Item 105

SOURCE	SS	MS	Df	F	P
Treatment	0.149	0.149	1	0.211	0.647
Within	169.430	0.712	238		

TABLE XXXII - continued

SUMMARY OF LINEAR DISCRIMINANT FUNCTIONS FOR STUDENT APPRAISAL OF STUDENT TEACHERS QUESTIONNAIRE ITEMS RELATED TO TEACHING AND QUESTIONNING EFFECTIVENESS

f. Item 106

SOURCE	SS	MS	Df	F	P
Treatment	0.066	0.066	1	0.095	0.759
Within	166.264	0.699	238		

g. Item 107

SOURCE	SS	MS	Df	F	P
Treatment	0.004	0.004	1	0.006	0.940
Within	164.155	0.690	238		

h. Item 108

SOURCE	SS	MS	Df	F	P
Treatment	0.338	0.338	1	0.697	0.405
Within	115.322	0.485	238		

i. Item 109

SOURCE	SS	MS	Df	F	P
Treatment	0.337	0.337	1	0.475	0.491
Within	169.156	0.711	238		

j. Item 110

SOURCE	SS	MS	Df	F	P
Treatment	-0.000	-0.000	1	0.000	1.000
Within	165.598	0.696	238		

k. Item 111

SOURCE	SS	MS	Df	F	P
Treatment	9.201	9.201	1	10.032	0.002
Within	218.289	0.917	238		

TABLE XXXII - continued

SUMMARY OF LINEAR DISCRIMINANT FUNCTIONS FOR STUDENT APPRAISAL OF STUDENT TEACHERS QUESTIONNAIRE ITEMS RELATED TO TEACHING AND QUESTIONNING EFFECTIVENESS

l. Item 112

SOURCE	SS	MS	Df	F	P
Treatment	0.149	0.149	1	0.190	0.663
Within	187.031	0.786	238		

m. Item 113

SOURCE	SS	MS	Df	F	P
Treatment	0.017	0.017	1	0.023	0.880
Within	172.630	0.725	238		

n. Item 114

SOURCE	SS	MS	Df	F	P
Treatment	0.267	0.267	1	0.300	0.585
Within	211.664	0.889	238		

o. Item 115

SOURCE	SS	MS	Df	F	P
Treatment	1.503	1.503	1	2.400	0.123
Within	149.056	0.626	238		

p. Item 116

SOURCE	SS	MS	Df	F	P
Treatment	6.669	6.669	1	8.984	0.003
Within	176.664	0.742	238		

q. Item 118

SOURCE	SS	MS	Df	F	P
Treatment	1.205	1.205	1	1.137	0.287
Within	252.288	1.060	238		

TABLE XXXII - continued

SUMMARY OF LINEAR DISCRIMINANT FUNCTIONS FOR STUDENT APPRAISAL OF STUDENT TEACHERS QUESTIONNAIRE ITEMS RELATED TO TEACHING AND QUESTIONNING EFFECTIVENESS

r. Item 119

SOURCE	SS	MS	Df	F	P
Treatment	1.505	1.505	1	2.013	0.157
Within	177.955	0.748	238		

s. Item 120

SOURCE	SS	MS	Df	F	P
Treatment	1.067	1.067	1	1.171	0.280
Within	216.913	0.911	238		