# THE EFFECT OF TWO TYPES OF ASSIGNMENT ON PERFORMANCE ON EXAMINATIONS IN HIGH SCHOOL

by

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## ABSTRACT

The aim of this study was to compare the effects of two types of study assignment on the achievements of high school students on three types of biology examination. One examination consisted of objective questions, a second of subjective questions of the short essay type, while the third was a combination of objective and subjective questions. One type of assignment consisted of questions of the objective type, the other of questions of the short essay type. Of related interest were the possible effects of a high percentage of objective examination questions, on the use by teachers of essay assignments.

An experiment of the matched parallel groups type was carried out. The experimental variable was the type of study assignment given, consisting of either objective or short essay questions. The duration of the experiment was six weeks, the academic subject field was biology, the groups received similar teaching, and comparisons were made on the results of specially constructed tests administered before and after the teaching period. Each test consisted of an objective examination and an essay examination. The mean gains of the two groups on each type of examination were compared. Results on what could be considered a mixed examination were obtained by combining the results of the objective and essay examinations. The objective and essay parts were weighted in such a way that the mixed

examination could be considered to resemble the type of examination in biology set by the British Columbia Department of Education. A final comparison was made between students' results on the experimental tests and on the actual departmental examination. Attempts were made to establish the validity and reliability of the objective test but it was not possible to establish any particular degree of validity or reliability for the essay test. After statistical treatment, it was found that there was no significant difference at the five percent level between the results of the groups on any of the three experimental tests. Some difficulty was experienced in comparing the results of the experimental tests with those of the departmental examination. This was due to the system of recommendation which does not require the top sixty percent to write the departmental examination, making it impossible to obtain a representative sample for comparison in this study.

Certain conclusions were drawn subject to the limitations of the tests and of the general experimental conditions. Comparing the use of objective and essay study assignments:- (1) there seemed to be no difference in the effect on the results on an objective test. Teachers and their students might feel free to use either type of study assignment in biology, (2) nothing in the study indicated any difference in the effect on an essay test, (3) nothing in the study indicated any difference in the effect on a combined objective-essay test of the type used by the Department of Education, (4) nothing in the study indicated that the use of one type of study assignment rather than the other would hamper a

student's chances of success on a biology examination of the type set by the Department of Education.

In summary it may be said that the type of examination in biology set by the British Columbia Department of Education did not appear to place any restriction on the type of study assignment used in high schools, provided that the assignments were comprehensive in their cover of the material under study.

I wish to express my gratitude to the following persons for assistance received in completing this study: Dr. Nagaswari Rajaratnam, my thesis adviser, Mr. Roland Anderson, who assisted in marking the tests, Mr. Robert Bruce for reading the manuscript, and Mr. Tomo Naka, who checked the statistical calculations. My thanks are also due to the principal and staff of L. V. Rogers High School for their interest and patience during the period of the experiment.

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# CHAPTER I

## THEME WRITING AND OBJECTIVE EXAMINATIONS

### Examinations and teaching practices.

This study arose as a result of general concern with the effects of current examination methods on high school teaching practices, in particular on the type of written assignment designed by high school teachers as a learning experience for their pupils. It is widely felt that the objective type of question which constitutes such a large part of present day examinations, colours the whole approach to high school studies and has a restrictive effect on certain teaching practices which may be of value in fostering educational development in the fullest sense. For instance, it is felt by many teachers that the regular writing of essay themes in subjects such as social studies and the sciences cultivates much that is desirable in the educational growth of students. Such teachers are not satisfied, however, that essay writing is good preparation for objective examinations. It is a common assumption that there is an incompatability between the achievement of broad educational aims and the satisfactory preparation for examinations of the objective type. There is little, if any, evidence to support or refute such an assumption, particularly at the high school level.

It seems likely that, for school and public examination purposes, the use of objective tests will continue. Under most conditions they are superior to essay tests in reliability, validity, and ease of scoring. A number of questions could be asked however, which seem to be pertinent to the bearing of objective examination on school and college education. What do they measure? Do students with a thorough knowledge and understanding of the subject matter do better than those who have made a selective study of aspects of the subject field susceptible to objective testing? What effect do these examinations have on students' methods of study? How much are the methods used by a school teacher influenced by the objective examination which his students will write at the end of his course?

Objective examinations and student attitudes to study.

In what way, if any, do students allow their methods of study to be influenced by the type of examination they will have to sit? Douglas and Talmadge[1] found that students who expected to be tested by objective examinations prepared and learned tables of facts and minute details of the material covered and tried to learn the wording of the textbook on important points, whereas those who anticipated testing by essay-type questions studied generalities and trends, formulated personal opinions about the material studied, attempted

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[1] H. R. Douglas and M. Talmadge, "How University Students Prepare for New Types of Examinations". School and Society 39, 1934, pp. 318 - 320.

to draw conclusions from prepared tables and studied their lecture notes generally. The investigators reached the conclusion that the type of examination does influence methods of study, objective examinations focusing attention on detail and exact wording whilst essay examinations favoured methods involving organization of material, perception of relationships and trends and the formation of personal attitudes to the subject matter.

In another study, Meyer[2] concluded that students expecting to be tested by essay questions took a wholistic view of their subjects, attempting to see first the general outline or "major drift" of the material under study, memorizing later such detail as time permitted. Those studying with an objective examination in mind frankly admitted concentrating on the learning of minutiae and definitions. One student said he "stuffed" his memory with as many facts as he could before the examination and then forgot most of them.

Summarizing this field, Freeman[3] says, "I believe our students are obtaining a wrong concept of what study means and that the real aims of instruction are being distorted".

Objective Examinations and teacher attitudes.

Concerning the attitudes of some teachers to courses

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[2]G. Meyer, "An Experimental Study of Old and New Types of Examination, II: Methods of Study". Journal of Educational Psychology 26, 1935, pp. 30 - 40.

[3]F. N. Freeman, "The Monopoly of Objective Tests". Educational Forum 10, 1946, pp. 389 - 395.

terminating in objective examinations, Stalnaker[4] says that it is hard to blame a teacher whose success may be judged by the scores obtained by his pupils on an objective examination involving no writing, if he reduces the amount of written work done in his classes. Certainly the idea that public examinations of the objective type foster a "quiz-kid" or slot-filling mentality in students and teachers is one that is frequently heard in high school staff rooms. Many teachers say that they feel that there is much of value for students in regular theme writing in many high school subjects, but that the objective examinations which most students will write limit the number of theme writing assignments which they feel justified in giving.

Important though it is, the passing of the final examination is a limited objective for a high school course. It would seem to be desirable that, at the end of any course, each student should be, to the extent of his ability, a better educated person in that particular field of knowledge than he was at the beginning; that he should have a feeling for the subject as a whole and its place in the field of human endeavour, and be able to interpret, evaluate and apply to new situations, the knowledge gained; that he should be able to express himself at length on some aspects of the subject.

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[4] J. M. Stalnaker, "The Essay Type of Examination", Educational Measurement, ed. E. F. Lindquist, Ch. 13, p. 515, Washington, D. C.: American Council of Education, 1951.

While an atomistic approach to the subject, such as might be encouraged by study with an objective examination in mind, may help a student to these ends, many teachers feel that the organizing of ideas in essay form provides a more promising approach.

An examination should be a measure of one or more desirable outcomes of education, not an end in itself. A well designed examination may, to some extent, measure the degree of development of the foregoing ideals. A poorly designed one may be quite unrelated to them. Certainly the examination should be the servant of the course, not the master. Nevertheless many courses of study do lead to public examinations and teachers are obliged to do all they can to see that at least the deserving students pass. For such students the public examination may be the only gateway to institutes of higher learning. The teacher's ability to hold his position or obtain advancement may depend on such tangible outcomes as the examination successes of his pupils, rather than on intangibles such as his abilities as an inspiring teacher. It seems then that the high school teacher has to be aware of two goals, the examination at the end of the course and the ideals and attitudes which he would like his students to acquire as a result of their studies under his guidance.

The role of the study assignment.

The study assignment is one of the teacher's principal tools for guiding the learning of his pupils. Discussing the assign-study-recite method of teaching so much used at

the high school level, Burton[5] says, "The assignment is the key to teaching and to learning under this organization. The assignment largely determines the results achieved." In the widest sense, the answering of an oral question is as assignment, but, and this applies particularly to high school students, a great deal of assignment work consists of a search for relevant information and its organization in some recorded form. The value attached to good assignments is emphasized in the findings of a study by Woodring and Fleming[6] who investigated the problems experienced by 230 teachers in connection with study assignments. Many of them expressed difficulty in designing assignments which were acceptable to students as worthwhile activities, included challenges to mental exploration, and provided for continuity of work.

If, as is generally claimed, assignment work bears heavily on the achievement of students, then the teacher must have his aims clearly in mind when designing his assignments. As has already been suggested, it is the opinion of many teachers and students that, where the examination takes the objective form, students who are given objective-type study assignments will do better than those given essay-type assignments. The latter type may be a more effective aid to the achievement of wider educational goals.

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[5] W. H. Burton, The Guidance of Learning Activities, p. 336, New York: Appleton-Century-Crofts, 1952.

[6] M. N. Woodring and C. W. Fleming, Directing the Study of High School Pupils, New York: Teachers College, Columbia University, 1929.

This poses two questions. The first is, "Does essay writing have the value so often attributed to it, of fostering desirable educational outcomes?" The other is, "From the point of view of passing an objective examination, are objective-type practice assignments in fact better than essay-type assignments?" The first question is important and should provide an interesting field for research. However, it is not the purpose of this study to deal with it.

The second question is of immediate and practical interest to the high school teacher concerned with more than his students' examination results. Its solution might well lead an interested teacher to investigate the first question. It is with this second question that this study is principally concerned.

There appear to be no previous published studies of the problem of the relationship between essay writing and objective examinations in the high school situation. Lundahl and Mason[7], working with university students compared essay and objective type assignments and found no significant difference in their effect on writing skills. The duration of the experiment was limited to four weeks and involved the writing of four long essays. In another study among university students, Meyer[8]

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[7]W. S. Lundahl and J. M. Mason, "Essay Testing in Biological Sciences as a Means of Supplementary Training in Writing Skills". Science Education 40, 1956, pp. 261 - 267.

[8]G. Meyer, "An Experimental Study of the Old and New Types of Examination, I: The Effect of Examination Set on Memory". Journal of Educational Psychology 25, 1934, pp. 641 - 661.

found a distinct advantage for an essay question "set" over an objective question "set", in achievement on various types of essay and objective examination. These students were older than high school students, their studies were unguided and the subject matter was historical. The findings do not necessarily apply to younger students working under considerable teacher guidance, especially if the subject is a branch of the sciences.

It is the main purpose of this study to try to throw some light on the relative effect on results in an objective examination, of essay and objective type assignments, within the limited field of a single science course offered in the British Columbia High School system. Once the matched groups and experimental material were assembled for the purpose, it was found possible to compare also the relative effectiveness of the two types of assignment on an essay test and on a mixed test, merely by adding an essay test to the original objective test to be given. These two comparisons are therefore included as secondary investigations. Finally, some comparisons are made between student attainment during the period of the experimental part of the study and success on the appropriate Department of Education final examination.

The study is not primarily concerned with trying to determine which is the better type of study assignment from the point of view of student success in examinations. Rather it is devised to investigate the degree to which a teacher whose students will be faced with an objective examination,

may feel free to assign essay questions, during the teaching of his course, if he feels that these have desirable outcomes. If students who have been given objective assignments do better on objective examinations than those who have been given essay assignments, then the teacher may feel restricted as to the amount of essay writing he gives. If there is no difference, or if the essay-writing students do better, then the teacher may feel free to assign as much essay writing as he feels to be appropriate, without fear of handicapping his students on the examination.

# CHAPTER II

## AN OUTLINE OF THE STUDY

### The problem.

The aim of this study was to compare the effects of essay and objective study assignments on student achievement in a biology examination consisting of questions of the type set on the British Columbia Department of Education Junior Matriculation Examination for the Biology 91 course. The experimental work was done at L. V. Rogers High School, Nelson, British Columbia, during the Biology 91 course which preceded the examination conducted by the Department of Education in June, 1961. The departmental examination usually consists of objective questions worth about ninety percent of the marks and short essay questions worth about ten percent. The principal purpose of the study was to compare the effects of the two types of assignment on achievement on an objective examination comprising questions of the type used in the departmental examination. Additional to this was a comparison of achievement on an essay examination and on a mixed examination whose objective and essay sections carried marks values similar to their relative values on a typical departmental examination. These additional aims were attempted by including an essay examination and combining the results of the two examinations, suitably weighted, to simulate a mixed test. A final comparison was made between the students'

results on the experimental examinations and on the departmental examination.

In this study the term "objective question", whether applied to assignments or examinations, includes multiple choice, matching, and completion questions. The use of completion questions is limited to those involving the insertion of the missing word in a sentence, or the supplying of the single word answer to a question of a highly objective nature.

The term "essay question" refers to a question normally requiring an answer of one or more paragraphs, although occasionally single sentence answers would be acceptable. Such a question gives relatively little guidance to the student as to the nature or form of the answer. It requires him to exercise initiative and formulate a free response essentially planned and executed by himself.

Delimitation of the study.

An attempt was made to establish the comparison of results on the objective test as a valid, controlled experiment. Because of the difficulty of establishing the reliability of the essay test, no attempt was made to establish as statistically valid, the comparisons of results on the essay and mixed tests. These results were processed statistically however and comparisons were made in the light of the conditions under which they were obtained.

The essay questions used in the assignments and tests required answers from one sentence to one or two paragraphs

in length. The initiative for formulating the answers came from the student but answers of this length probably do not require the same degree of forethought or such an overall view of the subject matter as do lengthy themes occupying a number of pages. The subject matter was mainly biological and ecological involving the formation of concepts and the understanding of relationships and applications as well as a knowledge of material facts. Answers to essay questions in such a field are hardly comparable with lengthy themes of a literary or philosophical nature. Any conclusions drawn from this study about the bearing of essay writing on examination results should be limited to short answers to questions in a scientific field. The findings may also be of some interest to teachers in other fields, such as social studies, where essay questions of a similar type may sometimes be used.

Hypothesis.

The hypothesis proposed was that there would be no significant difference between the achievements on the objective, essay or combined tests, of the two groups of students, the one group having been given objective assignments, the other group essay assignments. To minimize the danger of accepting the hypothesis when it was in fact false, that is of committing a type II error, the null hypothesis was proposed at the five percent level of confidence.

An outline of the experiment.

The experiment was carried out using parallel matched groups over a period of approximately six weeks in October and November of 1960. The matched groups were selected from three of the five classes of Grade XI students in the Biology 91 course at L. V. Rogers High School.

The time of the year was chosen as one when students would be well settled in school routine and there would have been time to establish rapport between the students and the experimenter who was the biology teacher. Previous records showed it to be a time of good attendance. The period of six weeks allowed the presentation of a quantity of subject material which constituted a reasonable entity, without clashing with school examinations.

The experimental plan was to administer to both groups an initial test of the biological field to be covered, to follow this with a period of instruction using similar teaching methods but different types of study assignment, and to conclude with a final test similar to the initial test. The teaching period included 15 lessons and three laboratory periods. The initial and final test each consisted of an objective and an essay examination.

The mean gain in marks from the initial to the final test was calculated for each group and the statistical significance of the difference between mean gains was calculated. Attempts were then made to draw conclusions

about the bearings of the different types of assignment on achievement in examinations of the types set and about the degree to which the departmental examination limits the teacher's freedom to set essay questions as assignments.

# CHAPTER III

## THE PERFORMANCE OF THE EXPERIMENT

### Preparation of the materials.

(i) The Tests.

The same tests were used for the initial and final testing. At the time of the initial testing the students had very little knowledge of the material under test, nor was there any indication at that time that they were to be tested again later, on the same material. The interval between initial and final testing was nearly six weeks. It seems unlikely that there could be any carry-over from the initial to the final testing periods. However, as the purpose of the testing was to measure gain in achievement, it was necessary to test for any slight initial knowledge the students might have.

It might be thought that ideally the examinations should be devised by some person other than the investigator, who designed the teaching material and assignments. In practice, however, the teaching material, assignments, and examinations were all prepared by the investigator. It would have been difficult to find another person sufficiently qualified in the subject matter and experimental technique and sufficiently aware of the objectives of the study to design valid examinations. The experimenter was aware of the need to avoid

any kind of bias and extreme care was taken to equate as nearly as possible the two types of assignment with each other and the two examinations with each other. The examinations were designed some weeks before the experiment was carried out while each pair of assignments was prepared, by referring to the material to be taught, only a few days prior to its use during the experimental period.

The objective and essay examinations were prepared in such a way that each one independently covered as fully as possible the content of the unit to be taught. The examinations were presented to the students as parts I and II of the same test, each part being designed for completion within an hour. A copy of the whole test is given in Appendix A.

Part I, the objective examination, contained 26 multiple choice questions, 25 matching questions, and 43 questions of the completion type. However, 17 of the completion questions involved selecting numbered items from diagrams and were, in effect, matching questions.

Part II, the essay examination, comprised 14 questions designed to be answered in a few sentences. An attempt was made to make the questions cover the same ground as that covered in the objective examination. The design of the questions probably has a great deal to do with the reliability and validity of an essay examination. From a series of studies,

Stalnaker[9,10,11] concludes that the objectives to be tested should be clearly defined and the scope of each question limited to one or, at the most, a very few objectives. He advises the use of many short questions and this is a technique also recommended by Thurstone[12]. Sims[13], as a result of experience gained in his many studies of methods of improving essay examinations, recommends that every question should isolate and limit the outcomes of learning to be tested. These recommendations were borne in mind when designing the questions.

A check of the face validity of the examinations was obtained by submitting them, together with an outline of the material covered, to various teachers of biology throughout the Province of British Columbia, with the request that they examine the tests in relation to the outline and give their opinions on the relevance of each examination. A comparison of the analysis of scoring according to context categories

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[9] J. M. Stalnaker and R. C. Stalnaker, "Reliability Reading of Essay Tests". School Review 42, 1934, pp. 599 - 605.

[10] J. M. Stalnaker, "The Problem of the English Examination". Educational Record 17 Supplement Number 10, 1936, pp. 35 - 48.

[11] J. M. Stalnaker, "Essay Examinations Reliably Read". School and Society 46, 1937, pp. 671 - 672.

[12] L. L. Thurstone, An Appraisal of the Test Movement, Proceedings 1936, Institute of Administrative Officers of Higher Institutions, Chicago: University of Chicago Press, 1936.

[13] V. M. Sims, "Essay Examination is a Projective Technique". Educational Digest 14, 1948, pp. 28 - 31.

when compared with the tables of specification provided evidence of content validity. Details of the evidence obtained for these aspects of validity are given in Appendix B.

The reliability of the objective examination was estimated by applying the Kuder-Richardson formula 20 to the results of the final test.[14] Details of the numbers of students completing correctly each test item in Part I, the objective test, are included in Appendix B. These were the figures used for calculating the reliability.

The method of marking an essay test has considerable bearing on its reliability. In Chapter I, several studies were quoted which illustrated the unreliability of much essay test marking. Studies by Sims[15] and Stalnaker[16] show that methods are available for improving the reliability of essay marking. Traxler and Anderson[17], in a study where the scoring was very carefully controlled, obtained a correlation of .94 between two markers. Many other studies could be quoted but the various methods of improving the

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[14] G. F. Kuder and W. M. Richardson, "The Theory of the Estimation of Test Reliability". Psychometrika 2, 1937, pp. 151 - 160.

[15] V. M. Sims, "Improving the Measuring Qualities of an Essay Examination". Journal of Educational Research 27, 1933, pp. 20 - 31.

[16] J. M. Stalnaker, "Essay Examinations Reliably Read", School and Society 46, November 20, 1937, pp. 671 - 672.

[17] A. E. Traxler and H. A. Anderson, "Reliability of an Essay Test in English". School Review 43, 1935, pp. 534 - 540.

reliability of the marking of essays are well summarized by Furst[18] and include:

(1) determining in advance the qualities to be judged.

(2) defining quality levels in advance of actual grading by such methods as preparing a model paper and reading a sample of papers.

(3) grading one question at a time.

(4) grading papers anonymously.

(5) using a team of readers and averaging the ratings.

These points were considered carefully when marking the essay test.

In an attempt to make the essay test as reliable as possible, particular care was taken with the preparation and marking of the questions. In order to provide some evidence as to reliability, the coefficient of correlation between the scores allocated by the two markers was computed.

(ii) The Assignments.

The experimental variable was the type of assignment to be given to each group of students. It was important that the conditions under which the assignments were completed should be carefully controlled and as similar as possible for the two groups. Conditions in the students' homes were considered to be too variable to allow the assignments to be done as homework. It was decided therefore to have them completed during the class periods. Half an hour was the usual time

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[18] E. J. Furst, Constructing Evaluating Instruments, New York: Longmans-Green, 1958.

allowed for each assignment. This meant that 35 minutes had to be allowed to cover the distribution, completion and collection of each assignment. This left 20 minutes of the 55 minute period as teaching time.

In view of the importance of the assignments in this experiment, it was necessary to ensure that they were the best that could be prepared. The following factors were particularly adhered to:

(1) Each assignment gave as complete a coverage as possible of the lesson which it followed, even if this involved some duplication.

(2) The coverage of the essay and objective assignments following a given lesson was as similar as possible. Any diagrams forming the basis of questions were used in both types of assignment.

(3) The questions were so designed that the students would be able to answer most of them correctly, without the answers being so obvious that there was a lack of challenge. A small percentage of more difficult questions was included to maintain the interest of more able students.

(4) The time necessary for completion had to be judged so that the assignments were finished, that is so that complete coverage of the material under study was achieved. At the same time, the two groups had to be actively engaged for similar lengths of time.

Hectographed assignment sheets of each type were prepared for each lesson, meeting, as nearly as possible, the foregoing requirements. Assignments of the two types were also prepared to follow the practical work in laboratory periods. Samples of the two types of assignment are included in Appendix C.

(iii) The Lesson Material.

In preparing the teaching material for each period, the following factors were considered to be particularly important:

(1) The requirements of the complete Biology 91 course necessitated the covering of a considerable amount of material during each lesson period. Theoretically, it would be desirable to deal with only one main topic during each period. Analysis of the Biology 91 syllabus in relation to the number of teaching periods available in the school year showed that an average of one and one half topics must be dealt with per lesson period.

(2) Only 20 minutes were available for teaching during each lesson period.

(3) Teaching variables were reduced as far as possible; that is the teaching experienced by the two groups had to be as similar as possible.

(4) There was no time for extensive reading of the textbook. Obviously students would not remember every point which arose during the teaching part of the lesson. They would require reference

material in order to complete their assignments. In this connection it should be mentioned that much of the material required in the Biology 91 course is not in the textbook. For the majority of students the teacher is the only source of this supplementary material.

To meet all these requirements brief but detailed hectographed notes were prepared for each lesson. It was not possible under the circumstances to provide much variety of approach except for the regularly spaced laboratory periods. During these periods the instructional time was increased to 30 minutes and consisted of practical work, with the examination of specimens and microscopic slides and the preparation of biological drawings. The assignment part of the lesson was represented by sets of questions of the two types, objective and essay, related to the practical work. Because of the limited scope of the material covered in the practical section of the laboratory period, the number of questions was reduced so that the work could be completed within the shorter time allowed for assignment work during laboratory periods.

Samples of lesson notes are included in Appendix C.

(iv) Assembly of the matched groups.

During the school year 1960 - 61 there were 5 classes of Biology 91 at L. V. Rogers High School. Three classes, consisting solely of students on the University Programme, were taught by the experimenter. These classes were known,

according to the timetable period in which they were taught, as Block A, Block C and Block D. The students were grouped with respect to ability in a fairly heterogenous manner although, on the average, the level of ability was highest in Block D and lowest in Block A. There was however, considerable overlap, there being in each block some very able students and some of limited ability. This arrangement proved to be very fortunate and made matching the groups a good deal easier than it might otherwise have been.

The group to be given the essay assignments, and known as the essay group, was chosen from the students of Block C, the class intermediate in ability and placed in the timetable between the other two classes. The other group, known as the objective group, was drawn from the students in Blocks A and D. The factors considered in matching were, previous achievement in Science and English Composition, Intelligence Quotients as measured by the Otis Test of Mental Ability Higher Examination Form C given in June 1959, age, results of the Gates Reading Survey Form I given in June 1959, and the sex of the students. Achievement in English Composition was included as a factor because of the prominence given during the experiment to the writing of essay type assignments and examination questions.

The maximum possible number of pairs was thirty, the number of students in Block C. It was anticipated that it would be impossible to match all of these. Similarity of achievement in Science and English were considered to be of

primary importance in the matching process. Where these achievements differed slightly more than seemed desirable, more rigid criteria were applied to the comparisons of intelligence quotients, chronological ages, and Gates reading ages. To satisfy these conditions, the matched pairs were assembled in two sets according to the following criteria:

Set 1:

Science and English grades the same or differing by one grade point. If both differed the differences must be in opposite directions.

Otis intelligence quotients not differing by more than twelve points.

Ages not differing by more than eight months.

Gates test not considered.

Set 2:

Science and English grades differing by not more than two grade points in opposite directions, or Science and English grades each differing by one grade point in the same direction.

Otis intelligence quotients not differing by more than four points.

Ages not differing by more than four months.

Gates reading ages not differing by more than 0.4 years. In both sets, students of like sex were matched together where it was possible to do this and still meet the foregoing criteria.

An estimate was made of the over-all effectiveness of the equating of the groups, by computing the means of the differences

between the matched students for the foregoing factors.

To counter the possibility of sub-conscious bias entering into the marking of the test papers, each student was given a number. The numbering was done randomly by another person and numbers were given to all students in Block A, C and D, whether they were included in the matched groups or not.

The administration of the experimental material.

An experiment of this nature could not possibly be hidden from the students being used as subjects, especially as they were older students, their average age being just over 16 years. Before the experimental period began therefore, the students concerned were told that they would be taking part in an educational experiment lasting about six weeks. It was explained that, for the experiment to be valid, it was necessary that they should do exactly as they were told and not try to influence the results by doing extra work or different work, or by any other means. In response to their natural curiosity it was explained that the less they knew about the nature and purpose of the experiment whilst it was in progress, the more valid the results were likely to be. A full explanation was promised after the conclusion of the experimental period. These students were familiar with the principals underlying scientific research and seemed able to appreciate these points.

The incidental benefits to the students were pointed

out. Work would be much more intense in class but there would be no homework. In fact they were especially requested not to attempt any study of biology outside the normal class hours. At the same time they were told that the instruction in class would probably be of a very high standard. Much more time would be given to the preparation of lessons than the teacher would normally devote and they would be provided with a great deal of hectographed material. Rapport between teacher and students was good and there seemed to be ready acceptance of the whole idea.

The initial test was presented without warning. The subjects were told that they were not expected to know much about the questions on the papers, that there was no stigma attached to a low mark or even to a zero mark, that they should not guess any of the answers but should definitely attempt each question to which they thought they knew the answer. No time limit was placed on either part and, in fact, all students had finished both parts of the test within an hour. The papers were identified by students' numbers, not by names. Each paper was marked by the experimenter and by a colleague, also a biology teacher. The markers worked independently. Particular care was taken with the essay section, as will be described in more detail in connection with the marking of the final test.

The lessons followed a fairly stereotyped pattern. The lesson notes were distributed prior to the commencement of the lesson period and were used as the basis of the twenty

minute teaching period. Fears that the inevitable similarity of presentation day after day might become monotonous proved to be groundless. The stimulus of knowing that an experimental study was in progress, the variety introduced by the occasional laboratory period, and the spirit of friendly competition between students within a class to excel in working the assignments, were all factors which seem to have helped to maintain interest.

After twenty minutes, during which the lesson notes were discussed, the appropriate type of assignment was distributed. All students in Block C were given essay assignments and all in Blocks A and D were given objective assignments. Immediately before the close of the lesson, the previous day's assignments, duly marked, were distributed. The current day's completed assignments were handed in as the students left the classroom at the conclusion of the lesson period. Assignments were identified by students' names, not by their numbers. Each day's assignments were marked in readiness for return to the students at the following lesson period. The experimenter marked the essay assignments and prepared the key to the objective assignments which were marked by an assistant.

Serious consideration was given to the problem of whether or not to return marked assignments to the students. There might be a danger of contamination if the students looked at each other's completed assignments. On the other hand it might be difficult to maintain the students' interest in daily assignments over a period of six weeks if they did not

see how their efforts were evaluated. The possibility of distributing the assignments and then collecting them again was excluded because of the limited time available in each lesson period. It was also felt that, at this age, students would be unlikely to spend much time out of school discussing details of school work and would be particularly unlikely to rework each others assignments. No doubt curiosity led the students of each group to look occasionally at the completed assignments returned to those in the other group, but it seems unlikely that they could learn any more from examining these assignments than they could have done from reading the hectographed sheets with which they had been provided. The value of assignments lies in completing them and in each student seeing the teacher's estimate of his efforts. In the interests of good rapport it was therefore decided to return the corrected assignments and to allow the students to keep them.

It was found that, in the early stages of the experimental period, the essay group attempted to answer their questions at too great a length and in too much detail. By the third or fourth lesson however, they had learned to limit the scope of their answers, concentrating on the details and ideas called for by the questions. The problem of getting the students to finish the essay assignments within the time available was one that persisted throughout the experiment and it may be that the students would have benefited more if

they had been allowed to complete then at home. The difficulty had been anticipated and was corrected to some extent by making the last question, usually the only one not completed, one of less importance than the others.

During the six week experimental period there were a number of absences. Fortunately the worst cases occurred amongst students not included in the matched groups. All students who had been absent were given the lesson and assignments they had missed, at midday breaks or after school. Attendance at these times was voluntary but students were very cooperative with the result that every student did all the assignments appropriate to his group.

The final test was administered without warning. One hour was allowed for each part. Part I, the objective examination, was given first and all students finished it before the end of the first hour. Part II was given during the second hour. Most students appeared to have sufficient time, but a very small proportion was still writing at the end of the hour allowed.

The whole test was marked independently by the two teachers who marked the initial test. The marking of the objective test presented no particular problem. The readers prepared independent keys and compared them to ensure agreement. Each page was then marked independently by each person and the marking compared as a check. For the marking of the essay test, the principles laid down on page 20 were adhered

to as closely as was practicable. Working independently, each reader considered each question in relation to the material taught and developed point by point answers. These independent keys were then compared and combined into an agreed marking key. Approximately twenty percent of the marks for each question were awarded for the quality of the presentation. The papers were graded anonymously, each one being identified by a number only. Before grading each question, a random sample of papers was read, to establish a general standard, especially for the quality of presentation. Each reader marked all the questions, but graded one question at a time throughout the who set of papers. Their independent gradings were then compared. Differences, which were suprisingly few, were discussed until an agreed mark could be allotted. Some idea of the extent of these differences can be gained from Table C in Appendix B.

Gains for each student on the final test over the initial test, were computed for Part I, Part II and for the combined parts. The formula used for obtaining combined scores was:

$$C = \frac{9A + B}{10}$$

Where C represents the score on the combined part, A the score on the objective part, and B the score on the essay part. Mean gains were calculated for the essay and objective groups and these gains and the differences between them were treated statistically to determine their significance.

## CHAPTER IV

## ANALYSIS OF THE RESULTS

The equality of the matched groups.

Block C, from which the essay group was drawn, numbered 30 students. Four of these were repeating the course and were not included in the experiment. The remaining 26 were matched as well as possible from Blocks A and D. One student from Block C left school before the experiment was completed. This left 25 suitable students in Block C. Of these, 15 were matched with students of Block A and 10 with students of Block D.

As might be expected students could not be matched perfectly for all factors. After following the procedures for matching as laid down in Chapter III[19], it was found possible to assemble 22 pairs according to the first set of criteria and three pairs according to the second. The three pairs were composed of students numbers 46 and 53, 108 and 57, and 20 and 77. In 21 pairs the sexes were similar but three girls and one boy of the essay group were matched with students of the opposite sex.

The averaging of school grade points and of intelligence quotients is not statistically sound, but to give a qualitative idea of the extent and direction of any over-all differences

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[19] page 24

between the groups, means were calculated for differences, between students in the matched pairs, of ages, intelligence quotients and grade points for previous work in Science and English. These mean differences are given in Table I. School grades at L. V. Rogers High School are awarded according to the usual seven point scale in use in British Columbia. Approximate percentages of students awarded each grade are:- A 5%; B 25%; C+ 15%; C 10%; C- 15%; D 25%; E 5%.

Table I

Mean differences between groups for matching factors.

| Factor | Mean difference (Objective - Essay) |
|---|---|
| English grade points | 0.04 |
| Science grade points | 0.32 |
| Intelligence quotients | 1.40 |
| Ages (Months) | 2 |

During the experimental period there were seventeen absences from lessons in each group. One student from each group was absent three times and this was the highest number of individual absences. All absentees subsequently studied the lesson material and did the assignments for each lesson they had missed. Details of the matching of pairs of students are given in Appendix D.

The validity of the test.

Both parts of the test, together with outlines of the biological field covered, were submitted to a number of teachers

of Biology at various high schools in British Columbia. They were asked to give their opinions on the validity of each part of the test; that is, each was asked to compare the test with the outline and say whether, in his opinion, each part provided adequate coverage of the biological field taught. The opinions of the teachers who replied are given in Appendix B, Section 2. The general consensus of opinion was that the validity of each part is high.

The reliability of the objective part was estimated by applying the Kuder-Richardson formula 20 to the results of the test.[20] According to the formula,

$$r = \frac{n}{n - 1}\left(1 - \frac{\Sigma pq}{\sigma^2}\right)$$

where $r$ = test reliability

$n$ = number of items in the test

$p$ = proportion of students passing each item

$q = 1 - p$

$\sigma^2$ = variance of the total scores on the examination

Details of the calculations of $\Sigma pq$ and $\sigma^2$ are given in Appendix B, Section 1, Tables A and B. There were 94 items on the objective part of the test,

$$\Sigma pq = 17.28, \quad \sigma^2 = 226,$$

therefore:-

$$r = \frac{94}{93}\left(1 - \frac{17.28}{226}\right)$$

$$= +0.93$$

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[20] G. F. Kuder and W. M. Richardson, op. cit.

In the opinion of the investigator this is a satisfactory figure for the reliability of this part.

No attempt was made to establish a statistical figure for the internal consistency of the essay part of the test. However, two factors probably have some bearing on any qualitative estimate of the validity of this part of the test. One is the general opinion on validity, already quoted. A second is the degree of agreement between the marks awarded by the two readers. This is summarized in Table C of Appendix B. The coefficient of correlation between the two readers was +0.95. There were very few questions not attempted. Forty-nine percent of all students taking the test, whether in the matched groups or not, attempted all the questions on the essay part. Of the fourteen questions on this part of the test, three were attempted by approximately eighty percent of the pupils. All the other questions were attempted by at least ninety percent. Approximately ninety-one percent of all possible answers were attempted.

Mean gains and their statistical significance.

Table II gives the values of $\overline{D}$, the mean difference in gains between paired students, for the three types of test. Values of $\overline{D}$ were obtained in each case by subtracting the mean gain for the objective group from that for the essay group, the difference between means being equal to the mean difference.

TABLE II

Mean differences in gains between groups

| Test | $\bar{D}$ Essay - Objective (raw score units) |
|---|---|
| Objective | -5.20 |
| Essay | -2.00 |
| Combined (Weighted) | -5.02 |

Details of the gains of each individual student, of the difference in gains between paired students, and of the calculation of $\bar{D}$ are given in Appendix E, Tables G and H.

For the estimation of the significance of the difference between correlated means for small samples, McNemar[21] gives the following formula for finding the t-ratio:-

$$t = \frac{\bar{D}}{S_{\bar{D}}}$$

$$S_{\bar{D}} = \sqrt{\frac{\frac{\Sigma(D - \bar{D})^2}{N - 1}}{N}}$$

where

$S_{\bar{D}}$ = estimate of the sampling error of the mean difference

D = difference in gain between paired students

N = Number of matched pairs

Calculations shown in Appendix E, Table H, give the values for $S_{\bar{D}}$ and t as shown in Table III.

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[21] Q. McNemar, Psychological Statistics, p. 226, New York: Wiley and Sons, Inc., 1949.

Table III

t ratios for mean differences in gains

| Test | $\overline{D}$ | $S_{\overline{D}}$ | t |
|---|---|---|---|
| Objective | 5.20 | 3.19 | 1.63 |
| Essay | 2.00 | 3.55 | 0.56 |
| Combined | 5.02 | 3.42 | 1.47 |

Entering the table of the distribution[22] of t for the numbers of degree of freedom, n, where:-

$$n = N - 1 = 24$$

it is seen that, for the differences to be significant at the five percent level of confidence, t must equal or exceed 2.064. The values of t shown in Table III fall considerably below this value.

Comparisons with the departmental examination.

Due to the system of passing by recommendation approximately sixty percent of the number of students eligible for departmental examinations, only forty percent of the students involved in the experiment actually wrote the examinations. This made it difficult to find a satisfactory basis of comparison between the experimental test results and student successes on the departmental examination. Table IV shows a comparison between the performances on the departmental examination in the essay and objective groups. Four students withdrew from the departmental examination and this involved altogether three of the matched pairs, reducing the number

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[22] Ibid. p. 368.

involved to forty-four.

Table IV

Comparisons between results on experimental tests and successes in the departmental examination.

| | Objective Group | Essay Group |
|---|---|---|
| Passed by recommendation | 13 | 13 |
| Passed by writing | 5 | 5 |
| Failed | 4 | 4 |

A further comparison was made by computing the biserial coefficient of correlation between results on the combined (experimental) examination and successes on the departmental examination. The formula used was:-

$$r_{bis} = \frac{M_p - M_q}{\sigma_t} \times \frac{pq}{y}$$

where:-

$M_p$ = mean on the combined examination for those passing the departmental examination.

$M_q$ = mean on the combined examination for those failing the departmental examination.

$p$ = proportion passing the departmental examination.

$q$ = proportion failing the departmental examination.

$\sigma_t$ = standard deviation of results on combined examination.

$y$ = ordinate of the normal distribution curve at the point of division between segments containing p and q proportions.

Substituting the appropriate data:

$$r_{bis} = \frac{63.1 - 46.5}{13.4} \times \frac{0.82 \times 0.18}{0.26}$$

$$= +0.70$$

It should be mentioned that recommendations were made on the basis of school examinations designed by the investigator in conjunction with another biology teacher. There may be a consistent tendency on the part of the investigator to examine in a particular way. Strictly speaking it is only in the case of students who wrote the departmental examination that comparisons can be made. The investigator feels however, that the combined examination provided a fairly satisfactory prognosis of success on the final examination.

# CHAPTER V

## INTERPRETATIONS AND CONCLUSIONS

Statistical significance of the results.

As stated on page 36, the values of t for the three experimental tests fall below the value 2.064 at which the difference between means would be significant at the five percent level. That is to say, differences as great as the obtained differences could occur in more than five cases out of every hundred due solely to chance errors in the sampling of the population. It can be said that at the five percent level of confidence the obtained differences in means are too small to be significant.

Conclusions.

Within the limitations of the conditions under which the experiment was carried out, the following conclusions may be drawn concerning the use of study assignments in the teaching of high school biology.

1. There is no significant difference between the results obtained on objective tests by students who study using objective assignments and by students who study using essay assignments. High school teachers and their students may therefore feel free to use either type of assignment in the study of a biology course terminating in an objective examination.

2. Assuming the essay examination used in this experiment to be valid and reliable, there is no significant difference between the results obtained on essay examinations by students who study using essay assignments and by students who study using objective assignments. Nothing in the study suggests that the use of objective rather than essay assignments, or vice versa, is likely to hamper students in answering any short essay questions included in a final examination.
3. Subject to the same reservations about the essay examination as were given in conclusion 2, there is no significant difference between the results obtained on a combined examination comprising about ninety percent objective and ten percent essay questions, by students who study using objective assignments, and by students who study using essay assignments. The final examination in Biology set by the British Columbia Department of Education is of this type.
4. It is doubtful if any valid conclusion can be drawn from the comparison between the results on the experimental test and the results on the departmental examinations. The experimental period covered the teaching of one unit of the course, comprising about eighteen percent of the material covered on the departmental examination. Any

differences which may have arisen on the departmental examination due to the experiment may well have been too small to be detected. It is felt, nevertheless, that some type of comparison had to be made. Had there been any significant difference between the final results for the two groups, this might well have been worthy of further investigation.

Limitations of the study.

The foregoing conclusions should be viewed in the light of the experimental conditions. Due to the requirements of a controlled experiment, some of these conditions were unlike those found in a normal school situation. For instance, students were not allowed to complete assignments outside the classroom. The teacher's methods of presentation, although similar for the two groups, were different from those normally used. Students were aware that an experiment was in progress. Although the relative benefits reaped from their assignments by the two experimental groups, may have been the same under more normal circumstances, the possibility cannot be ruled out that at least part of the results may have been due to the experimental conditions.

On the other hand, the exigencies of the normal school routine imposed some conditions far from ideal from the experimental point of view. For instance, it is impossible in a school situation to study a subject in isolation from other subjects. Students get experience of essay writing

and of selecting answers to objective questions from other subjects, and there may well have been techniques involved here which carried over from other subjects. Thanks to the utmost cooperation received from the school administration, there were no obvious instances of variation between presentations of the same lessons to the three blocks of students involved, but minute differences may still have existed. The rotating type timetable more or less eliminated variations of student attitude towards learning arising from differences of time of day.

Some degree of uncertainty exists as to the validity and reliability of the essay examination. However, the examination was very carefully constructed and a number of qualified teachers commented favourably on its validity. There was a high coefficient of correlation between the marks awarded by the two readers. Uncertainty as to the value of the examination should not be interpreted as suggesting that it was not a good examination. However, all conclusions resting to any degree on the results of the essay examination should be viewed with its possible limitations in mind.

Summary.

The results of this study suggest that, in the field of at least one high school subject, namely biology, the use of a high percentage of objective questions in a final examination, need not unduly restrict a teacher's choice

of the type of question to be used in study assignments, provided that the assignments as a whole are carefully prepared and provide good coverage of the particular area under study. In particular, the results suggest that a teacher should feel free to include short essay questions in his assignments, with reasonable confidence that, in addition to any value such questions may have with respect to general appreciation, they would also help students to acquire a knowledge of details and other aspects of the subject necessary to pass an examination which includes a high percentage of objective type questions.

Due to the practical limitations of the study and its main emphasis on the relationship between essay assignments and objective tests, considerable caution is necessary in summarizing the subsidiary findings. However, it can be said that nothing in this study suggests that the use of objective rather than essay assignments is likely to hinder students experienced in essay writing in other fields, from answering short essay questions included in an examination in biology. There is no evidence to prove that the type of biology examination set by the British Columbia Department of Education necessarily restricts high school biology teachers in the design of study assignments, provided a good coverage of the subject matter has been achieved.

Suggestions for further study.

Because of the need for a careful experimental control, this study was carried out under somewhat artificial conditions.

In practice students usually work on their assignments at home or during study periods and this gives them more time to complete the work. The limited number of students available prevented the use of a normal school set-up such as this for the experiment. Chance differences in home and study conditions might have been large enough to bias the results. If an investigation could be carried out involving a number of schools and several hundred pupils, it could reasonably be expected that such differences would tend to cancel out from group to group. A third group could be added for which the assignments were of a mixed type. Such mixed assignments are commonly used in practice.

It would be interesting to see the results of further studies involving other high school subjects. Social studies and other sciences suggest themselves. Such studies would be interesting not only because of their bearing on the individual subjects, but also because they might reveal a general pattern for the relationship between assignments and examinations. No such generalizations could possibly be drawn from a study such as this one, which was confined to a single academic subject.

APPENDIX A

COPIES OF THE TESTS

Note - In these copies, the answer blanks, diagrams and spacing have been reduced in size.

Student's Number .....

Scores:- Page 1 .....

L. V. Rogers High School
Nelson, B. C.

Page 2 .....

Page 3 .....

Biology 91

Page 4 .....

Final Test

Page 5 .....

Part I

Page 6 .....

Time allowed - 1 hour

Page 7 .....

Total _____

Part 2 _____

SECTION A

Select the best answer of those provided and place its number in the parentheses at the right.

1. The brown "spots" on the underside of a fern leaf are the:-
(1) sori (2) prothalli. (3) antheridia. (4) archegonia.
(5) annuli... . . . . ( )

2. The collapse of a cell due to loss of water is called:-
(1) diffusion. (2) imbition. (3) plasmolysis. (4) turgor.
(5) translocation. . . . . ( )

3. The type of root system which serves best to bind soil particles together, thus preventing erosion, is:-
(1) rhizome. (2) tap root. (3) diffuse root. (4) rhizoid.
(5) tuberous root . . . . . ( )

4. Bryophytes and Pteridophytes tide over unfavourable periods in the form of:- (1) zygotes. (2) spores.
(3) gametes. (4) seeds. (5) rhizoids. . . . . ( )

5. A member of the phylum Bryophyta is:- (1) Lichen.
(2) Reindeer Moss. (3) Sphagnum Moss. (4) Protococcus.
(5) Club Moss . . . . . ( )

6. The tissues which make up the bulk of a mature Douglas Fir tree are composed of:- (1) cambium. (2) cortex. (3) xylem. (4) phloem. (5) pith. . . . . ( )

7. The strawberry plant reproduces sexually by means of:- (1) spores. (2) runners. (3) rhizomes. (4) budding. (5) seeds. . . . . ( )

8. Gymnosperm seeds possess:- (1) one cotyledon. (2) two cotyledons. (3) two dicotyledons. (4) more than two cotyledons. (5) no cotyledons. . . . . ( )

9. The term "gymno" as in Gymnosperm means:- (1) naked. (2) wood. (3) floor. (4) cone. (5) wheat . . . . . ( )

10. An example of a dicotyledon is:- (1) corn. (2) bamboo. (3) onion. (4) tomato. (5) wheat . . . . . ( )

11. Which one of the following is an immediate product of photosynthesis:- (1) oxygen. (2) water. (3) carbon dioxide. (4) chlorophyll. (5) radiant energy. . . . . ( )

12. Foods may be tested for the presence of starch by the addition of a little:- (1) hydrochloric acid. (2) sodium carbonate. (3) iodine. (4) Fehling's solution. (5) litmus solution . . . . . ( )

13. The rate of transpiration from a plant is speeded up by:- (1) high humidity. (2) strong winds. (3) low temperature. (4) absence of soil water. (5) decreased leaf surface area . . . . . ( )

14. Plant leaves with stomata evenly distributed on both epidermal surfaces would be found to have a growth habit described as:- (1) completely aquatic and unspecialized as in the kelp. (2) leaves growing in a vertical position as in the grasses. (3) lower epidermis upward facing the sun, as in the water lily. (4) lower epidermis downward shaded from the sun, as in the maple tree . . . . . ( )

15. The male sex cells of a flowering plant are produced in the:- (1) pistil. (2) stigma. (3) testis. (4) ovule. (5) pollen . . . . . ( )

16. Of the following, the best description of a rhizome is:- (1) a shallow root. (2) an underground stem. (3) a deep root swollen with stored food. (4) a rhizoid. (5) a large underground bud, with fleshy leaves. . . . . ( )

17. Thin walled cells separating the vascular tissues in a woody stem and extending from the cortex to the pith are called:- (1) annual rings. (2) xylem. (3) cambium. (4) cork. (5) pith rays. . . . . ( )

18. A flower having stamens and lacking a pistil is described as:- (1) imperfect. (2) hermaphrodite. (3) parthenogenetic. (4) perfect. (5) bisexual. . . . . ( )

19. In a flower when the receptacle completely encloses the ovary and the petals arise from the receptacle edge on top of the ovary, the ovary is said to be:- (1) inferior. (2) superior. (3) hypogynous. (4) imperfect. (5) perfect( )

20. Cambium produces new growth:- (1) in the xylem only. (2) in the xylem and pith. (3) in the phloem only. (4) in the xylem and phloem. (5) in the xylem, phloem and pith rays . . . . . ( )

21. The generative nucleus produces two structures called:- (1) cotyledons. (2) ovules. (3) sperms. (4) tube nuclei. (5) pollen grains. . . . . ( )

22. Which of the following is the best description of the sporophyte in Liverworts? (1) small, conspicuous and dependent. (2) large, conspicuous and dependent. (3) microscopic, inconspicuous and dependent. (4) large, conspicuous and independent. (5) microscopic, inconspicuous and independent. . . . . ( )

23. Plant leaves require a supply of oxygen:- (1) intermittently. (2) at night only. (3) day and night. (4) during the day only . . . . . ( )

24. Winged seeds are produced on exposed shelf-like scales, by plants of the group:- (1) dicotyledons. (2) angiosperms. (3) monocotyledons. (4) gymnosperms. (5) maples . . . . ( )

25. An indirect product of photosynthesis is:- (1) oxygen. (2) fat. (3) sugar. (4) water. (5) carbon dioxide. . . . ( )

26. A plant whose leaves are fairly thick with few stomata and two crowded palisade layers, would probably be found in an environment which is:- (1) sunny and wet. (2) shaded and wet. (3) sunless and dry. (4) cold and wet. (5) sunny and dry. . . . . ( )

## SECTION B

Items in the left-hand columns are arranged alphabetically, Read the items in the right-hand columns, then enter in the parentheses the number of the items in the left-hand column most closely associated with it. Some numbers may be used more than once, some not at all.

1. Match the description with the phylum.

(1) All plant phyla
(2) Bryophyta
(3) No plant phylum
(4) Pteridophyta
(5) Spermatophyta
(6) Thallophyta

The sporophyte is dependent on the gametophyte. . . . . ( )
Reproduce both sexually and asexually. ( )
Conspicuous sporophyte. The gametophyte is microscopic and dependent on the sporophyte. . . . . ( )
The zygote becomes an embryo within the seed . . . . . ( )
Dominant tree-like plants in the carboniferous period as shown by fossil patterns in present day coal seams . . . . . ( )
Classified in four groups according to colour. . . . . ( )
Ancient plant forms still in existence from this phylum include horsetails and club mosses. . . . . ( )
Phylum best adapted for desert existence. . . . . ( )

2. Match the description with the part of a seed plant.

(1) Bark
(2) Cambium
(3) Cortex
(4) Epidermis
(5) Medullary ray
(6) Phloem
(7) Root cap
(8) Root hair
(9) Root tip
(10) Stoma
(11) Xylem

Transparent cells with cutinous protection .( )
Unspecialized cells between xylem and phloem; able to form new cells . . . . . .( )
Chief region of food storage in perennial plants . . . . . .( )
Loose cells protecting the end of a root . .( )
Tissues conducting water and dissolved minerals . . . . . .( )
A minute projection from an epidermal cell .( )
Diffusion of gases takes place through this pore in the leaf surface . . . . . .( )
Provides the chief supporting tissue of dicot stems. . . . . .( )

3. Match the description with the substance.

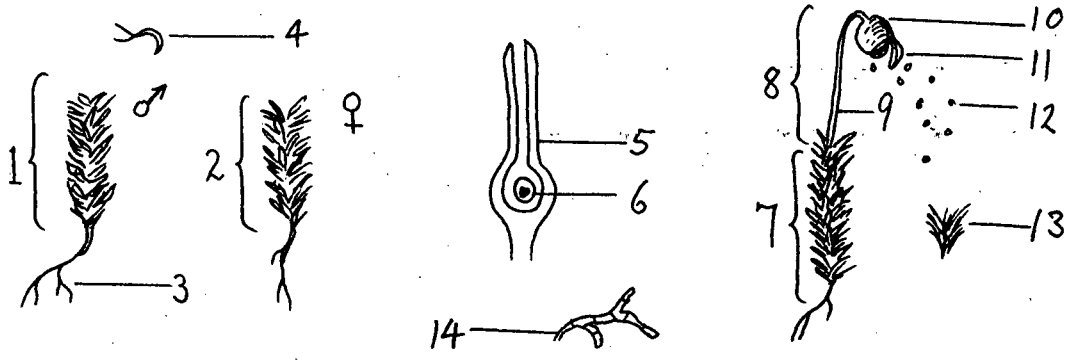
| | | |
|---|---|---|
| (1) Calcium carbonate | | |
| (2) Cellulose | Grit in the stem of a horsetail. . . . . | ( ) |
| (3) Protein | Wood in a pine tree. . . . . | ( ) |
| (4) Silica | Storage form of food in a flowering plant. | ( ) |
| (5) Starch | Primary food manufactured in photo- | |
| (6) Sugar | synthesis . . . . . | ( ) |

4. Match the description with the part of the seed.

| | | |
|---|---|---|
| (1) Cotyledon | During germination, roots will develop from | |
| (2) Embryo | the lower end of this structure . . . . . | ( ) |
| (3) Hilum | Principal store of food in a dicot stem . . | ( ) |
| (4) Hypocotyl | The tough outer coat of the seed. . . . . | ( ) |
| (5) Micropyle | Represents the point where the pollen tube | |
| (6) Plumule | entered the ovule . . . . . | ( ) |
| (7) Testa | In the bean seed, consists of two minute | |
| | green, leaflike structures folded | |
| | together. . . . . | ( ) |

## SECTION C

The diagrams below represent stages from the life cycle of moss.




1. Which number represents the beginning of the gametophyte generation? . . . . . ( )

2. Which number represents a resistant-walled, asexually-reproductive structure? . . . . . ( )

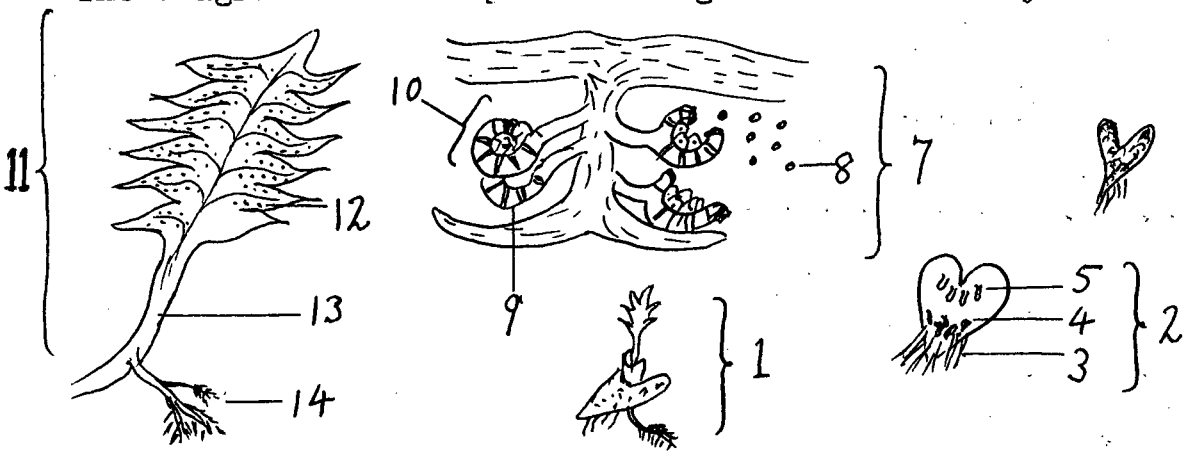
3. Which number represents a dependent generation? . . . ( )

4. Which of the following numbers represents a structure which is part of the sporophyte generation? - 1, 5, 9, 13, 14 . . . . . ( )

5. Name structure number 14 . . . . . .....

6. Name structure number 3. . . . . .....

The diagrams below represent stages in the life cycle of a fern.




7. Structure number 7 is an enlargement of structure number . . . . . .....

8. Give the number of the structure in which male gametes are produced . . . . . .....

9. Which number represents:- (a) a prothallus? . .....

(b) a sporangium? . .....

(c) a mature sporophyte.....

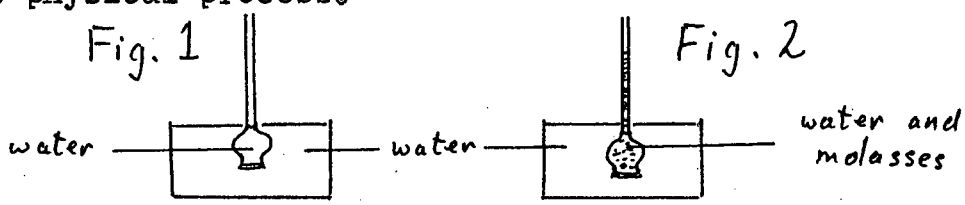
10. Name structure number 13. . . . . .....

11. Name structure number 9 . . . . . .....

12. What is the function of structure number 9? .....

.....

The diagrams below represent an experiment to demonstrate an important physical process.

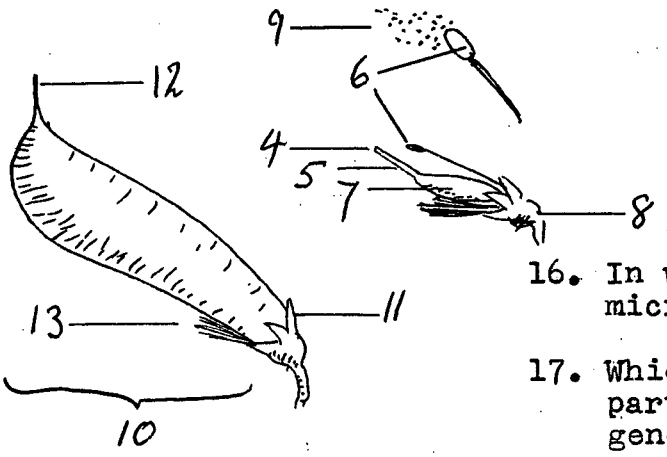


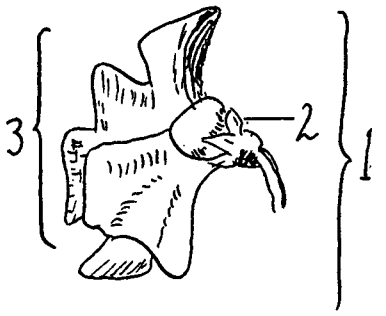

13. In this experiment the apparatus shown at Fig. 1 is known as the . . . . . .....

14. The process by which the water passes through the membrane is called . . . . . .....

15. The membrane, freely permeable to water but not to molasses is said to be. . . . . .....

The diagrams below represent the parts of a flower and their subsequent development.




16. In which number would the microspore be found? . . .....

17. Which number represents a part of the gametophyte generation? . . . . . .....

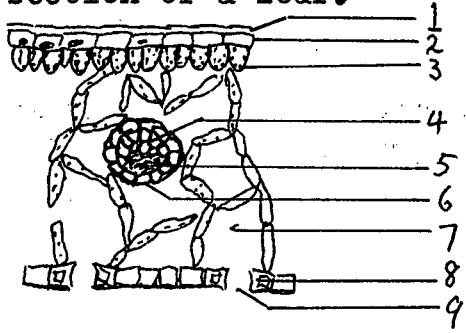
18. What biological name is given to part number 10? . . .....

19. Part number 10 is formed by the enlargement of another part. What number represents this other part? . . . .....

20. Name part number 4 . . . . . .....

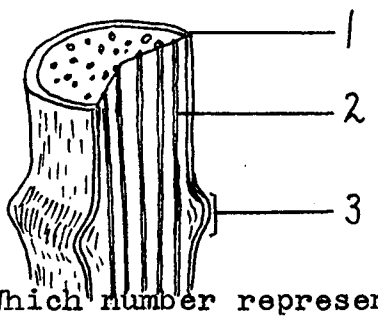
21. All the parts numbered 3 together make up the. . . . .....

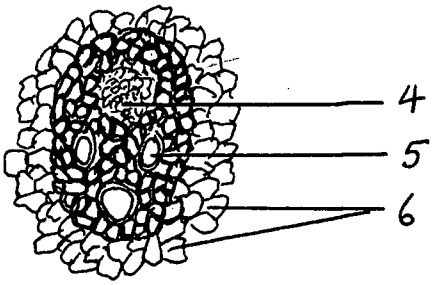
The figure below is a diagrammatic representation of the cross-section of a leaf.




22. Give the number of a structure which brings water for photosynthesis from the root . . . . . .....
23. What other material for photosynthesis, enters the leaf at number 9?. . . . . .....
24. Name part number 8 . . . . . .....
25. Give the name of the actual structures in which photosynthesis occurs. . . . . .....
26. Give the number of the cell which controls the rate of loss of water from the leaf. . . . . .....

Diagram A represents a plant stem with a portion removed to show the internal structure. Diagram B is a highly magnified cross-section of structure number 2.




27. Which number represents the chief supporting tissue of this stem? . . . . . .....
28. Which number represents the tissue specialized for the conduction of food material vertically in the stem? . . . . . .....
29. Which number represents the chief storage tissue of this stem? . . . . . .....
30. Name part number 3 . . . . . .....
31. Describe the leaf venation characteristic of this stem. . . . . .....

## SECTION D

Answer the questions or complete the statements by supplying the missing words or phrases. Answer at the right of the question.

1. The raw material from which bees manufacture honey is called (1) . . . . . (1).....
2. Flowers having no petals or scent glands, but with abundant pollen, will probably be pollinated by the agency of (2). . . . . (2).....
3. Fruits which become dry and then "explode" or forcibly eject their seeds are described as being(3).....
4. The transfer of food products from the manufacturing area in the leaf to storage areas in the roots or stem is called (4) . . . . . (4).....
5. Organisms having male and female sex organs on separate individuals are said to be (5) . . . (5).....
6. Roots arising from stem or leaf tissues are called (6) roots. . . . . (6).....
7. A flower which has pistils, stamens, petals and sepals is described as being. . . . . (7).....
8. In grafting shrubs and trees, the part to be grafted to the root or stock is called the. . (8).....
9. Plants which complete their life cycle in one year are classified as (9) plants . . . . . (9).....
10. The movement of any substance through a semi-permeable membrane, from a place of greater concentration to one of lesser concentration, is known as . . . . . .(10).....

Student's Number .....

L. V. Rogers High School
Nelson, B. C.

Biology 91

Scores

| | |
|---|---|
| 1. ..... | 8. ..... |
| 2. ..... | 9. ..... |
| 3. ..... | 10. ..... |
| 4. ..... | 11. ..... |
| 5. ..... | 12. ..... |
| 6. ..... | 13. ..... |
| 7. ..... | 14. ..... |

TOTAL _____

PART II

Answer the following questions in paragraph form. Some answers will be longer than others but the average time for each one should be between 4 and 5 minutes.

A. Compare, among mosses, ferns and seed plants:-

1. Alternation of generations, with respect to the degrees of dependence, conspicuousness and size of the two generations.

2. The formation and distribution of spores.

3. The methods used to survive periods of drought.

B. Compare:-

4. The adaptions of diffuse roots and tap roots.

C. Describe:-

5. The tissues of a dicot stem, giving their functions and any specific uses they may have for man.

6. The course of pollination and fertilization in a seed-bearing plant which has imperfect flowers.

7. How a plant makes starch and how its presence in a leaf may be demonstrated.

8. How the various parts of a flower become modified to form parts of the fruit and seed.

9. The process of seed germination, mentioning any differences between the various classes of plants.

D. Discuss:-

10. The transference of water, minerals and food substances in plants.

11. A plant cell's need for water and what happens when water is short.

12. The ways in which plant leaves, stems and roots may be adapted to various types of environment.

13. The adaptions for pollination which may be shown by a flower.

E. Trace:-

14. The course of energy from sunlight to the movement of a cat, mentioning all the transformation processes involved.

## APPENDIX B

## VALIDITY AND RELIABILITY OF THE TESTS

### 1. Reliability of the objective test.

Table A shows the values of p, the proportion of students passing each question, and of q(= 1 - p), the proportion failing each question.

TABLE A

| Ques. | p | q | pq | Ques. | p | q | pq | Ques. | p | q | pq |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A 1 | .98 | .02 | .020 | vii | .69 | .31 | .214 | 12 | .77 | .23 | .177 |
| 2 | .85 | .15 | .123 | viii | .51 | .49 | .250 | 13 | .82 | .18 | .148 |
| 3 | .94 | .04 | .040 | 2. i | .84 | .16 | .134 | 14 | .73 | .27 | .197 |
| 4 | .89 | .11 | .098 | ii | .88 | .12 | .106 | 15 | .94 | .06 | .056 |
| 5 | .57 | .43 | .245 | iii | .63 | .37 | .233 | 16 | .53 | .47 | .249 |
| 6 | .62 | .38 | .236 | iv | .77 | .23 | .177 | 17 | .47 | .53 | .249 |
| 7 | .40 | .60 | .240 | v | .72 | .28 | .202 | 18 | .62 | .38 | .236 |
| 8 | .37 | .63 | .233 | vi | .83 | .17 | .142 | 19 | .44 | .56 | .246 |
| 9 | .86 | .14 | .120 | vii | .95 | .05 | .049 | 20 | .67 | .33 | .221 |
| 10 | .14 | .86 | .120 | viii | .62 | .38 | .236 | 21 | .40 | .60 | .240 |
| 11 | .87 | .13 | .113 | 3. i | .85 | .15 | .128 | 22 | .57 | .43 | .245 |
| 12 | .95 | .05 | .048 | ii | .91 | .09 | .082 | 23 | .67 | .33 | .221 |
| 13 | .15 | .85 | .218 | iii | .85 | .15 | .128 | 24 | .91 | .09 | .082 |
| 14 | .90 | .10 | .090 | iv | .94 | .06 | .056 | 25 | .15 | .85 | .128 |
| 15 | .61 | .39 | .238 | 4. i | .57 | .43 | .245 | 26 | .76 | .24 | .182 |
| 16 | .74 | .26 | .192 | ii | .60 | .40 | .240 | 27 | .65 | .35 | .228 |
| 17 | .87 | .13 | .113 | iii | .58 | .42 | .244 | 28 | .35 | .65 | .228 |
| 18 | .99 | .01 | .010 | iv | .80 | .20 | .160 | 29 | .78 | .22 | .172 |
| 19 | .61 | .39 | .238 | v | .68 | .32 | .218 | 30 | .83 | .17 | .142 |
| 20 | .45 | .55 | .248 | C 1 | .47 | .53 | .249 | 31 | .60 | .40 | .240 |
| 21 | .61 | .39 | .238 | 2 | .39 | .61 | .238 | D 1 | .84 | .16 | .134 |
| 22 | .52 | .48 | .250 | 3 | .79 | .21 | .166 | 2 | .96 | .04 | .040 |
| 23 | .59 | .41 | .242 | 4 | .64 | .36 | .230 | 3 | .65 | .35 | .228 |
| 24 | .70 | .30 | .210 | 5 | .58 | .42 | .244 | 4 | .87 | .13 | .116 |
| 25 | .44 | .56 | .246 | 6 | .71 | .29 | .206 | 5 | .49 | .51 | .250 |
| 26 | .43 | .57 | .245 | 7 | .89 | .11 | .098 | 6 | .43 | .57 | .245 |
| B 1i | .74 | .26 | .192 | 8 | .50 | .50 | .250 | 7 | .74 | .26 | .192 |
| ii | .31 | .69 | .214 | 9a | .80 | .20 | .160 | 8 | .79 | .21 | .160 |
| iii | .46 | .54 | .248 | 9b | .65 | .35 | .228 | 9 | .90 | .10 | .090 |
| iv | .79 | .21 | .166 | 9c | .57 | .43 | .245 | 10 | .45 | .55 | .248 |
| v | .70 | .30 | .210 | 10 | .67 | .33 | .221 | Part total = 5.594 | | | |
| vi | .51 | .49 | .250 | 11 | .69 | .31 | .214 | | | | |
| Part total- 5.694 | | | | Part total - 5.993 | | | | TOTAL ($\Sigma pq$)= 17.281 | | | |

$\Sigma pq$ for the Kuder-Richardson formula 20 = 17.281

The calculation of $\sigma^2$ for the Kuder-Richardson formula 20 is taken from the frequency distribution shown in Table B.

TABLE B

| Raw score | f | d | fd | $fd^2$ |
|---|---|---|---|---|
| 85 - 89 | 6 | 6 | 36 | 216 |
| 80 - 84 | 11 | 5 | 55 | 275 |
| 75 - 79 | 14 | 4 | 56 | 224 |
| 70 - 74 | 8 | 3 | 24 | 72 |
| 65 - 69 | 6 | 2 | 12 | 24 |
| 60 - 64 | 10 | 1 | 10 | 10 |
| 55 - 59 | 15 | 0 | 0 | 0 |
| 50 - 54 | 7 | -1 | -7 | 7 |
| 45 - 49 | 9 | -2 | -18 | 36 |
| 40 - 44 | 2 | -3 | -6 | 18 |
| 35 - 39 | 5 | -4 | -20 | 80 |
| 30 - 34 | 3 | -5 | -15 | 75 |
| SUMS | 96 | | 127 | 1037 |

$$\sigma^2 = i^2 \left[ \frac{\Sigma fd^2}{N} - \left( \frac{\Sigma fd}{N} \right)^2 \right]$$

$$\therefore \sigma^2 = 25 \left[ \frac{1037}{96} - \left( \frac{127}{96} \right)^2 \right]$$

$$\therefore \sigma^2 = 25 \quad (10.80 - 1.75)$$

$$\therefore \sigma^2 = 226$$

2. Reliability of the essay test.

Table C summarizes the differences between the marks allotted by the two readers for each essay question. The number of times the marks differed is shown for each question, for each of the amounts:-

Reader A minus Reader B = +2, +1, 0, -1, -2.

There were no differences of more than two marks.

The mean difference in marks for each question is expressed as a percentage of the average mark "$\bar{X}$" gained by the students on that question. A bracketed negative sign before this percentage indicates that the mean difference, as derived from the foregoing expression, was negative; that is there was a tendency for Reader B to mark higher than Reader A.

The total number of students writing the test was 96 and the number who answered each question is shown under "n".

TABLE C
Comparison of marks awarded by the readers

| Question number | Max. mark | n | $\bar{X}$ | Numbers of differences +2 | +1 | 0 | -1 | -2 | Mean difference (as % of $\bar{X}$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 89 | 7.0 | 1 | 4 | 78 | 6 | 0 | 0 |
| 2 | 8 | 92 | 3.0 | 2 | 2 | 85 | 3 | 0 | 1.1 |
| 3 | 4 | 89 | 1.8 | 0 | 4 | 84 | 1 | 0 | 1.9 |
| 4 | 6 | 88 | 2.9 | 0 | 3 | 77 | 7 | 1 | (-)2.4 |
| 5 | 15 | 92 | 9.1 | 3 | 11 | 76 | 2 | 0 | 1.8 |
| 6 | 12 | 91 | 3.7 | 0 | 2 | 86 | 3 | 0 | (-)0.3 |
| 7 | 8 | 91 | 4.8 | 0 | 2 | 84 | 5 | 0 | (-)0.7 |
| 8 | 6 | 84 | 3.2 | 0 | 3 | 81 | 0 | 0 | 1.1 |
| 9 | 11 | 79 | 4.1 | 1 | 1 | 75 | 2 | 0 | .3 |
| 10 | 8 | 95 | 4.0 | 0 | 2 | 84 | 7 | 2 | (-)2.4 |
| 11 | 8 | 95 | 3.6 | 0 | 3 | 91 | 1 | 0 | 0.6 |
| 12 | 13 | 87 | 5.5 | 1 | 5 | 78 | 3 | 0 | 0.8 |
| 13 | 12 | 90 | 4.3 | 0 | 2 | 84 | 4 | 0 | (-)0.5 |
| 14 | 10 | 78 | 3.5 | 0 | 6 | 71 | 1 | 0 | 1.8 |
| Totals | 133 | 1240 | 60.5 | 8 | 50 | 1134 | 45 | 3 | |

These differences, if allowed to stand, would have resulted in differences in the total scores awarded to individual students by the two readers. A coefficient of correlation between the two readers was calculated for these circumstances and found to be +.95.

3. Validity of the tests.

The same table of specification, as shown in Table D, was used for the two tests.

TABLE D

Table of specification

| Subject matter area | Concepts % | Applications % | Facts % | Totals % |
|---|---|---|---|---|
| Bryophyta | 4 | 1 | 5 | 10 |
| Pteridophyta | 3 | 2 | 9 | 14 |
| Spermatophyta | 1 | 1 | 4 | 6 |
| Roots | 3 | 1 | 7 | 11 |
| Stems | 3 | 4 | 8 | 15 |
| Leaves | 4 | 6 | 8 | 18 |
| Reproduction | 8 | 3 | 8 | 19 |
| Fruits, seeds | 2 | 1 | 4 | 7 |
| Totals | 28 | 19 | 53 | 100 |

Table E shows the analyses of scoring for the two tests. Comparison with the table of specification (Table D) will give an idea of the content validity of each of the tests.

TABLE E

Analyses of scoring according to subject matter areas

Part A (Objective Test)

| Subject matter area | Concepts % | Applications % | Facts % | Totals % |
|---|---|---|---|---|
| Bryophyta | 4.4 | 0.8 | 4.8 | 10.0 |
| Pteridophyta | 2.8 | 1.9 | 9.0 | 13.7 |
| Spermatophyta | 1.6 | 0 | 3.5 | 5.1 |
| Roots | 3.1 | 1.6 | 6.9 | 11.6 |
| Stems | 3.1 | 4.2 | 8.5 | 15.8 |
| Leaves | 4.2 | 5.8 | 8.0 | 18.0 |
| Reproduction | 8.1 | 3.0 | 7.8 | 18.9 |
| Fruits, seeds | 1.6 | 1.1 | 4.2 | 6.9 |
| Totals | 28.9 | 18.4 | 52.7 | 100.0 |

Part B (Essay Test)

| Subject matter area | Concepts % | Applications % | Facts % | Totals % |
|---|---|---|---|---|
| Bryophyta | 1.5 | 2.3 | 1.5 | 5.3 |
| Pteridophyta | 1.5 | 2.3 | 1.5 | 5.3 |
| Spermatophyta | 2.3 | 3.0 | 2.3 | 7.6 |
| Roots | 3.8 | 4.6 | 3.0 | 11.4 |
| Stems | 6.9 | 4.6 | 7.6 | 19.1 |
| Leaves | 6.5 | 6.9 | 6.5 | 19.9 |
| Reproduction | 5.0 | 4.6 | 8.8 | 18.4 |
| Fruits, seeds | 3.8 | 2.3 | 6.9 | 13.0 |
| Totals | 31.3 | 30.6 | 38.1 | 100.0 |

The following are extracts from all the letters received from teachers who examined the tests for face validity. The only omissions are those of a personal or irrelevant nature. Nothing has been omitted which related to validity.

From Mr. A. Enns of Williams Lake Junior-Senior High School:-

1. Part I: Objective examination is well constructed and covers the material very adequately. The only minor negative criticism I may have is that Section 14 of the outline received somewhat shallower treatment than did the

other topics. However, the variety of questions, choice of distractors in the multiple choice questions and the diagrams are all superb.

2. Part II: The 14 essay topics are excellent and cover the work well. I especially favour section A. One would have to know how the class was taught before it could be decided what entirely is desired in question 4. I am not too sure what my class would understand by the word "adaptions"..... adaptions in growth as related to stem, secondary roots, adaptions of root hairs, to climate, depth, and necessary absorptive surface. Actually the question does cover a fair amount of material.

The questions are not all of the same weight. Question 1 is much more difficult than numbers 7 and 14.

3. The sample assignments are obviously the follow-up of a well organized lesson. They certainly demand thought on the part of the student. If he applies himself to the assignments there should be no doubt as to his comprehension of the material in the lesson or his ability to pass the designed unit test. If all assignments were of this high calibre, my negative criticisms of Part II would be invalid.

In closing may I again say that both parts, each in its own way, covers the unit thoroughly as it is designed and in an interesting and challenging manner.

From Mr. John A. G. Blackwell of Max Cameron Senior High School, Powell River.

Part I: Course content is covered with exception that

there is no mention of tropisms or types of fruits.

The items of section A are good, the choices are related to subject involved in question.

The items of section B are typical. I especially like question #3, page 4.

Diagrams and questions of section C are satisfactory and cover course content well.

Question 4, section D are excellent but I feel more of this type should have been used. However, since I assume that this was a period test you have covered the course content adequately.

Part II: The items test are valid as far as course content is concerned but I feel that they are too difficult and too numerous to be answered well by most Biology 91 students.

From Mr. S. D. Foreman of Howe Sound Junior-Senior High School.

In reply to your request for an opinion on the content validity of Part I, I would say that the validity would be very high. I find it hard to confine myself to only a statement on the validity, however, I will do so and again state that the teaching unit seems well covered or so validity is high.

Part II: The essay exam naturally can be high or low when end results are seen. The exam itself or the questions asked do cover the entire field and therefore the content validity of the exam is high, however, without the lead words I'm sure the answer paper wouldn't lead one to believe that the validity was very high.

APPENDIX C

TEACHING AND ASSIGNMENT MATERIAL

1. Copy of the teaching unit.

The Development of the Spermatophytes

1. Phylum Bryophyta - Mosses and Liverworts.
   Structure, lifecycle, elementary physiology.
   Alternation of Generations.
   Position in the plant kingdom.

2. Phylum Pteridophyta - Ferns, Horsetails, Club Mosses.
   As for Bryophyta - comparisons between Bryophyta and Pteridophyta.

3. Phylum Spermatophyta.
   Position in plant kingdom.
   General functions of plant organs.
   Classification as applied to Spermatophyta.

4. Root Systems.
   Types, structures and functions.
   Diffusion, etc.

5. Absorption of water and salts.

6. Stems.
   Types in relation to environment.
   Structure, functions, growth.

7. Herbaceous dicot and monocot stems.
   Comparisons.
   Internal structures.
   Specializations.
   Grafting, pruning.

8. Structure of leaves.
   General functions.
   External and Internal Structures.

9. Functions of leaves.

10. Storage and use of foods in plants.
    Translocation, respiration, transpiration, etc.

11. Experiments with leaves.
    Production of starch and oxygen, transpiration.

12. Reproduction of Gymnosperms and Angiosperms.
    General principles.
    Comparisons.
    Angiosperms - floral parts, types of flower.

13. The Roles of Stamens and Pistil.
    Alternation of generations in angiosperms - comparisons with Bryophytes and Pteridophytes.
    Pollination and adaptations for

14. Fertilization and the development of seeds.
    Development of fruits.
    Structure of typical fruits.

15. Structure and germination of seeds.

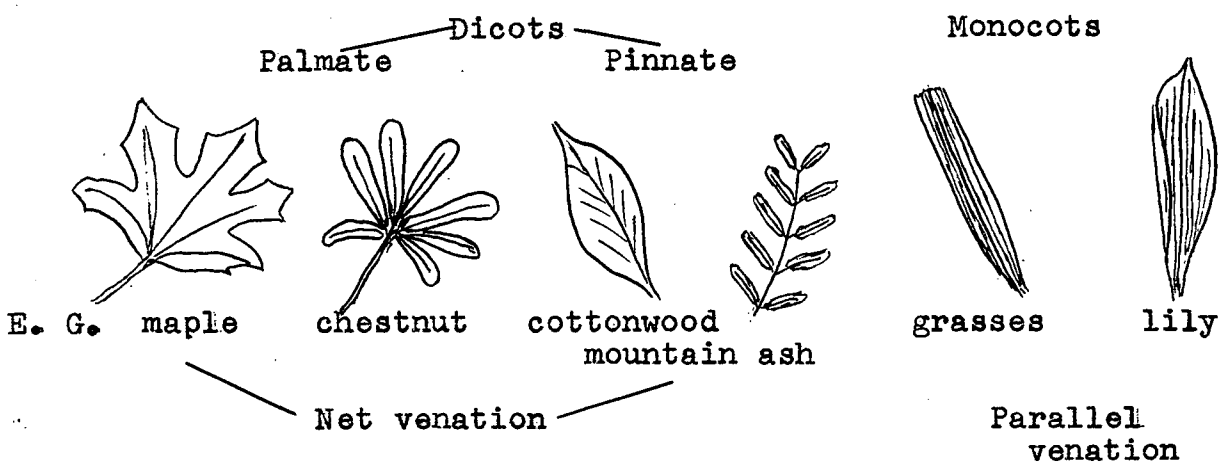
2. Sample of lesson notes and accompanying assignments.

Notes 8 THE STRUCTURE OF LEAVES

Functions of Leaves
(1) Photosynthesis - the manufacture of food - the principal function.
(2) Respiration - oxygen absorbed, carbon dioxide given off through stomata - minute pores that cover the leaf surface.
(3) Transpiration - the discharge of water through stomata.
ALSO - (4) storage, (5) reproduction.

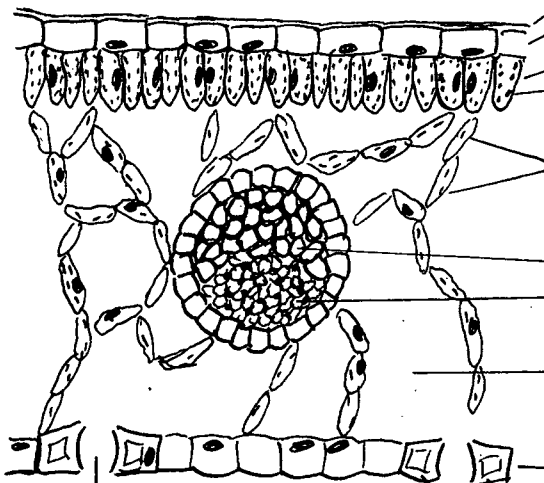
General Structure
Blade - strengthened and supplied by veins (fibrovascular bundles)
Petiole - the leaf stalk - veins extend through petiole and join fibrovascular bundles of stem. Petiole joins stem at node. Stalkless leaves are said to be "sessile".

Leaf venation:-



## Internal Structure of Leaves

Cross-section



Cuticle (non-cellular)
Epidermis - transparent, admits light, prevents loss of water.
Palisade cells - photosynthesis
Chloroplasts - contain chlorophyll
thin-walled, irregularly shaped cells - temporary storage
Xylem } Vein - fibrovascular bundle
Phloem }
Air spaces - circulate oxygen, carbon dioxide and water vapour
Lower epidermis
Guard cells - change in their turgor opens or closes the stomata. Regulates diffusion of oxygen and carbon dioxide, transpiration.
Stoma (pl. stomata) -the pores in the surface of the leaf

Stomata - 60,000 to 450,000 per sq. inch. In terrestrial plants- usually on lower surface; if leaves vertical - on both surfaces; water lily - on upper surface only. Also on epidermis of herbaceous stems. Note - woody stems have "lenticels" - much more robust than stomata.

Chlorophyll - carbon, hydrogen, oxygen, nitrogen and magnesium - complex.

Photosynthesis - using carbon dioxide & producing oxygen - during daylight hours only.

Respiration - using oxygen and producing carbon dioxide - day and night. During daylight, when photosynthesis is occurring, the leaf produces more oxygen than it uses - thus disguising the respiration.

Assignment A8 Name .....

## THE STRUCTURE OF LEAVES

a. 1. Match the leaf structure with the description:-

(1) Cutin
(2) Epidermis
(3) Guard cell
(4) Palisade cell
(5) Spongy mesophyll
(6) Stoma
(7) Vein

Continuous with phloem and xylem of stem . . . . . ( )
A wax-like coating on the surface of the leaf . . . . . ( )
Cell containing many chloroplasts. . . ( )
Includes many spaces which provide for diffusion and interchange of gases. . . . . ( )
Point of entry for oxygen for respiration . . . . . ( )
Structure whose size is regulated by two specialized cells . . . . . ( )
A cell which occurs in both upper and lower epidermis of an upright leaf. . . . . ( )
Provides temporary storage for manufactured food . . . . . ( )
When water is short, this cell changes shape and reduces loss of water by transpiration. . . . . ( )
Provides the strengthening framework of the leaf. . . . . ( )

2. Match the leaf characteristic with the description:-

(1) Palmate
(2) Parallel
(3) Pinnate
(4) Sessile

Applied to a leaf whose blade is attached directly to the plant stem . . . . . ( )
Main veins of the leaf radiate from a single point . . . . . ( )
Characteristic of cottonwood and apple trees. . . . . ( )
Characteristic venation of corn leaves. . . ( )
Applied to leaves with no petiole . . . . . ( )

3. Select the living process which best fits each description

(1) Photosynthesis
(2) Reproduction
(3) Respiration
(4) Storage
(5) Translocation
(6) Transpiration

Characteristic of cambium tissue . . . ( )
Occurs in all living plant cells continuously. . . . . ( )
The giving off of water vapour from plant leaves, stems and fruits. . . ( )
The transfer of food material. . . . . ( )
Produces gaseous oxygen. . . . . ( )
Principal function of phloem tissue. . ( )
Regulated by highly specialized cells in the leaf epidermis . . . . . ( )

4. Match the type of plant with the description:-

| | | |
|---|---|---|
| (1) All dicots | Parallel veined leaves . . . . . | ( ) |
| (2) Herbaceous dicots | Net veined leaves. . . . . | ( ) |
| | Stems have separate vascular bundles arranged in a ring formation. . . . . | ( ) |
| (3) Monocots | | |
| (4) Woody dicots | Photosynthesis can occur in both leaves and stems. . . . . | ( ) |

b. Complete the following:-

(1) Minute pores that cover the surface of the leaf are called . . . . . (1) .....

(2) Large pores in the surface of woody stems are called. . . . . (2) .....

(3) The constituent of photosynthesis conveyed to the leaf by xylem is. . . . (3) .....

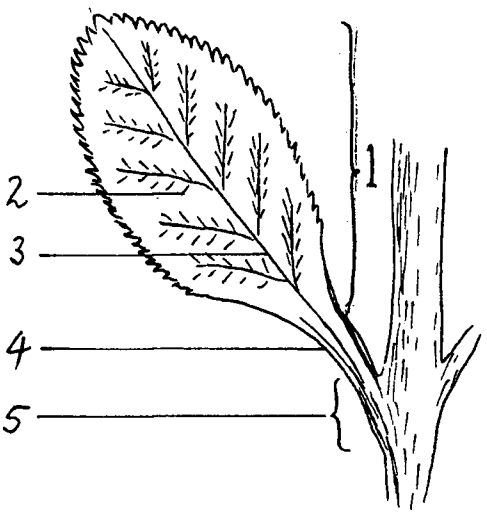
(4) The green pigment to be found in most plants is called (4) and is made up of carbon, hydrogen, oxygen, (5) and (6) . . . . . (4) .....
(5) .....
(6) .....

(7) The term mesophyll is made up of "meso", coming form the Greek word meaning (7) and "phyll", coming from the Greek word meaning (8). . . . . (7) .....
(8) .....

(9) A non-cellular secretion of the epidermis of the leaf is (9). . . . . (9) .....

(10) The leaf tissue most concerned with preventing undue loss of water is the (10) .....

c. Answer the following question about the leaf illustrated:-




Name the following structures:-

Structure number 1 .....

Structure number 3 .....

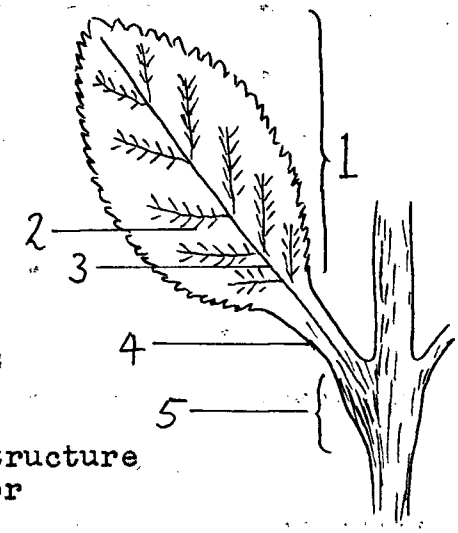
Structure number 4 .....

Name two tissues to be found in structure number 2 .....

Underline any of the following adjectives which apply to the venation of this leaf:-

Net; Pinnate; Palmate; Parallel

Assignment 8B THE STRUCTURE OF LEAVES




(1) Describe the visible structures of the illustrated leaf and its point of attachment to the stem. What other method of attachment is there and what adjective is applied to it. (The numbers are for you to use in your description if you wish.)

(2) Describe the structure and functions of the vein of a leaf.

(3) Compare the leaf venation of monocots and dicots.

(4) Name and describe the position and structure of the cells of a leaf responsible for photosynthesis.

(5) Describe the ways in which a leaf regulates and prevents loss of water.

(6) Trace the path of water from the leaf xylem to the outside air. What is this process called?

(7) Very briefly compare photosynthesis and respiration. (Include the times of day when they occur.)

APPENDIX D

DETAILS OF MATCHING OF GROUPS

Table F shows the comparisons between students in each of the factors on which pairs were matched.

TABLE F

| Student Number | Age Months Oct.60 | Sex | I. Q. (Otis) | Achievement Gates S.F.I. June,1959 | School Grades | |
|---|---|---|---|---|---|---|
| | | | | | Science | English |
| 25 | 192 | F | 114 | 11.8 | C | C+ |
| 110 | 191 | F | 119 | 11.1 | C | B |
| 134 | 190 | F | 106 | 11.1 | C- | B |
| 74 | 194 | F | 101 | 10.9 | C | C+ |
| 138 | 194 | F | 111 | 10.9 | C- | C- |
| 101 | 198 | F | 104 | 11.1 | C- | C |
| 151 | 190 | F | 105 | | C- | C |
| 153 | 197 | M | 105 | 10.9 | C | C- |
| 49 | 192 | M | 118 | 11.0 | B | C |
| 143 | 197 | M | 121 | | B | C |
| 71 | 192 | F | 128 | 11.5 | C | C+ |
| 142 | 193 | F | 127 | 11.6 | C | C |
| 18 | 199 | M | 115 | 10.4 | C+ | C |
| 120 | 196 | M | 114 | | B | C |
| 53 | 196 | F | 117 | 11.4 | B | C |
| 46 | 202 | F | 118 | | C+ | B |
| 75 | 193 | F | 124 | 11.4 | C+ | C+ |
| 97 | 198 | M | 124 | 11.4 | B | C+ |
| 40 | 193 | F | 127 | 11.0 | C+ | B |
| 140 | 195 | F | 131 | 11.0 | C+ | B |
| 103 | 195 | M | 119 | 11.3 | C+ | C |
| 80 | 198 | M | 125 | 11.3 | B | C+ |
| 45 | 191 | M | 116 | 9.5 | C | C |
| 29 | 189 | M | 124 | 9.7 | C | C |
| 133 | 201 | M | 125 | 10.1 | C- | C- |
| 44 | 200 | M | 121 | 10.1 | C- | C |

Continued overleaf.

| Student Number | Age Months Oct.60 | Sex | I. Q. (Otis) | Achievement Gates S.F.I. June, 1959 | School Grades | |
|---|---|---|---|---|---|---|
| | | | | | Science | English |
| 108 | 196 | F | 117 | 10.0 | C- | C- |
| 57 | 197 | F | 114 | 10.1 | C+ | C- |
| 20 | 198 | F | 115 | 10.8 | C- | C+ |
| 77 | 195 | F | 113 | 10.6 | C | B |
| 102 | 191 | M | 110 | 10.8 | C- | C |
| 68 | 198 | M | 107 | 9.9 | C- | C- |
| 42 | 196 | M | 123 | | B | C |
| 107 | 195 | M | 122 | 11.0 | B | C |
| 130 | 194 | M | 113 | 9.7 | C+ | B |
| 66 | 192 | M | 119 | 10.9 | C+ | B |
| 82 | 190 | M | 115 | 11.4 | C | C |
| 118 | 197 | M | 123 | 11.5 | C+ | C- |
| 30 | 190 | M | 115 | 10.9 | C- | C |
| 121 | 192 | M | 126 | 10.8 | C- | C |
| 31 | 199 | M | 115 | 11.3 | C | B |
| 85 | 195 | M | 123 | 11.0 | C | C+ |
| 104 | 199 | M | 117 | 10.9 | B | B |
| 81 | 198 | M | 119 | 10.3 | C+ | B |
| 69 | 202 | M | 109 | | C | C |
| 127 | 198 | F | 119 | 10.3 | C+ | C- |
| 117 | 190 | F | 120 | 11.0 | C | C+ |
| 26 | 195 | F | 126 | 10.5 | C | B |
| 112 | 195 | F | 114 | 11.0 | C- | C+ |
| 61 | 199 | M | 123 | 10.6 | C- | C+ |

## APPENDIX E

DETAILS OF SCORES, GAINS, AND CALCULATIONS OF $\overline{D}$ AND t.

Table G shows the scores and gains of each student in each part of the test and the differences in gains between students of each matched pair. Differences were obtained by subtracting the gain by the student in the objective group from the gain by the student in the essay group.

TABLE G

| Student Number | Objective Part Init. | Final | Gain | Essay Part Init. | Final | Gain | Differences (D) Obj. | Essay | Combined |
|---|---|---|---|---|---|---|---|---|---|
| 25 | 8 | 42 | 34 | 3 | 36 | 33 | -39 | -21 | -40.8 |
| 110 | 4 | 77 | 73 | 2 | 56 | 54 | | | |
| 134 | 2 | 57 | 55 | 0 | 47 | 47 | | | |
| 74 | 10 | 45 | 35 | 0 | 29 | 29 | 20 | 18 | 21.5 |
| 138 | 8 | 52 | 44 | 1 | 40 | 39 | | | |
| 101 | 12 | 47 | 35 | 0 | 18 | 18 | 9 | 21 | 10.8 |
| 151 | 3 | 37 | 34 | 2 | 32 | 30 | | | |
| 153 | 11 | 75 | 64 | 0 | 39 | 39 | -30 | -9 | -30.8 |
| 49 | 11 | 78 | 67 | 13 | 75 | 62 | | | |
| 143 | 18 | 86 | 68 | 3 | 88 | 85 | -1 | -23 | -2.9 |
| 71 | 8 | 61 | 53 | 1 | 52 | 51 | | | |
| 142 | 8 | 61 | 53 | 11 | 46 | 35 | 0 | 16 | 1.3 |
| 18 | 15 | 76 | 61 | 20 | 61 | 41 | | | |
| 120 | 3 | 72 | 69 | 0 | 57 | 57 | -8 | -16 | -9.3 |
| 53 | 4 | 67 | 63 | 14 | 62 | 48 | | | |
| 46 | 7 | 47 | 40 | 3 | 27 | 24 | 23 | 24 | 25.0 |
| 75 | 20 | 46 | 26 | 7 | 35 | 28 | | | |
| 97 | 13 | 80 | 67 | 1 | 67 | 66 | -41 | -38 | -44.2 |
| 40 | 6 | 72 | 66 | 3 | 60 | 57 | | | |
| 140 | 2 | 71 | 69 | 6 | 66 | 60 | -3 | -3 | -3.3 |
| 103 | 8 | 73 | 65 | 28 | 62 | 34 | | | |
| 80 | 3 | 70 | 67 | 4 | 41 | 37 | -2 | -3 | -2.3 |
| 45 | 8 | 45 | 37 | 4 | 32 | 28 | | | |
| 29 | 10 | 50 | 40 | 0 | 24 | 24 | -3 | 4 | -2.7 |

Continued overleaf.

| Student Number | Objective Part Init. | Final | Gain | Essay Part Init. | Final | Gain | Differences (D) Obj. | Essay | Combined |
|---|---|---|---|---|---|---|---|---|---|
| 133 | 5 | 30 | 25 | 0 | 9 | 9 | | | |
| 44 | 11 | 36 | 25 | 4 | 17 | 13 | 0 | -4 | -0.3 |
| 108 | 3 | 46 | 43 | 0 | 36 | 36 | | | |
| 57 | 13 | 63 | 50 | 11 | 39 | 28 | -7 | 8 | -6.3 |
| 20 | 5 | 58 | 53 | 2 | 60 | 58 | | | |
| 77 | 8 | 57 | 49 | 4 | 27 | 23 | 4 | 35 | 6.9 |
| 102 | 4 | 36 | 32 | 2 | 20 | 18 | | | |
| 68 | 4 | 55 | 51 | 14 | 40 | 26 | -19 | -8 | -19.7 |
| 42 | 12 | 78 | 66 | 0 | 74 | 74 | | | |
| 107 | 6 | 65 | 59 | 4 | 53 | 49 | 7 | 25 | 9.1 |
| 130 | 6 | 63 | 57 | 0 | 49 | 49 | | | |
| 66 | 6 | 76 | 70 | 0 | 60 | 60 | -13 | -11 | -13.9 |
| 82 | 4 | 56 | 52 | 0 | 55 | 55 | | | |
| 118 | 2 | 67 | 65 | 0 | 57 | 57 | -13 | -2 | -13.2 |
| 30 | 6 | 42 | 36 | 2 | 30 | 28 | | | |
| 121 | 3 | 39 | 36 | 3 | 32 | 29 | 0 | -1 | -0.1 |
| 31 | 9 | 62 | 53 | 0 | 43 | 43 | | | |
| 85 | 14 | 58 | 44 | 6 | 32 | 26 | 9 | 17 | 10.4 |
| 104 | 12 | 68 | 56 | 8 | 58 | 50 | | | |
| 81 | 6 | 74 | 68 | 4 | 70 | 66 | -12 | -16 | -13.3 |
| 69 | 6 | 62 | 56 | 3 | 71 | 68 | | | |
| 127 | 5 | 82 | 77 | 5 | 58 | 53 | -21 | 15 | -19.7 |
| 117 | 9 | 60 | 51 | 0 | 44 | 44 | | | |
| 26 | 10 | 61 | 51 | 3 | 45 | 42 | 0 | 2 | 0.2 |
| 112 | 5 | 48 | 43 | 0 | 33 | 33 | | | |
| 61 | 4 | 37 | 33 | 0 | 13 | 13 | 10 | 20 | 11.7 |

Table H and the subsequent section show the calculations of $\overline{D}$ and t for the three examinations

TABLE H

| Objective | | Essay | | Combined | |
|---|---|---|---|---|---|
| D | $D^2$ | D | $D^2$ | D | $D^2$ |
| -39 | 1521 | -21 | 441 | -40.8 | 1664.6 |
| 20 | 400 | 18 | 324 | 21.5 | 462.3 |
| 9 | 81 | 21 | 441 | 10.8 | 116.6 |
| -30 | 900 | -9 | 81 | -30.8 | 948.6 |
| -1 | 1 | -23 | 529 | -2.9 | 8.4 |
| 0 | 0 | 16 | 256 | 1.3 | 1.7 |
| -8 | 64 | -16 | 256 | -9.3 | 86.5 |
| 23 | 529 | 24 | 576 | 25.0 | 625.0 |
| -41 | 1681 | -38 | 1444 | -44.2 | 1953.6 |
| -3 | 9 | -3 | 9 | -3.3 | 10.9 |
| -2 | 4 | -3 | 9 | -2.3 | 5.3 |
| -3 | 9 | 4 | 16 | -2.7 | 7.3 |
| 0 | 0 | -4 | 16 | -0.3 | 0.1 |
| -7 | 49 | 8 | 64 | -6.3 | 39.7 |
| 4 | 16 | 35 | 1225 | 6.9 | 47.6 |
| -19 | 361 | -8 | 64 | -19.7 | 388.1 |
| 7 | 49 | 25 | 625 | 9.1 | 82.8 |
| -13 | 169 | -11 | 121 | -13.9 | 193.2 |
| -13 | 169 | -2 | 4 | -13.2 | 174.2 |
| 0 | 0 | -1 | 1 | -0.1 | 0.0 |
| 9 | 81 | 17 | 289 | 10.7 | 114.5 |
| -12 | 144 | -16 | 256 | -13.3 | 176.9 |
| -21 | 441 | 15 | 225 | -19.7 | 388.1 |
| 0 | 0 | 2 | 4 | 0.2 | 0.0 |
| 10 | 100 | 20 | 400 | 11.7 | 136.9 |
| $\Sigma D=130$ | $\Sigma D^2=6778$ | $\Sigma D=50$ | $\Sigma D^2=7676$ | $\Sigma D=-125.6$ | $\Sigma D^2=7632.9$ |
| N= 25 | | N=25 | | N= 25 | |
| $\overline{D}=5.20$ | | $\overline{D}=2.00$ | | $\overline{D}= 5.02$ | |

Calculations of $S_{\bar{D}}$ :-

$$S_{\bar{D}} = \frac{\sqrt{\frac{(D - \bar{D})^2}{N - 1}}}{\sqrt{N}}$$

$$= \frac{\sqrt{\frac{D^2 - \frac{(D)^2}{N}}{N - 1}}}{\sqrt{N}}$$

| Objective Test | Essay Test | Combined Test |
|---|---|---|
| $S_{\bar{D}} = \frac{\sqrt{\frac{6778 - \frac{(130)^2}{25}}{24}}}{\sqrt{25}}$ | $S_{\bar{D}} = \frac{\sqrt{\frac{7676 - \frac{(50)^2}{25}}{24}}}{\sqrt{25}}$ | $S_{\bar{D}} = \frac{\sqrt{\frac{7633 - \frac{(126)^2}{25}}{24}}}{\sqrt{25}}$ |
| $= \frac{\sqrt{\frac{6778 - 676}{24}}}{5}$ | $= \frac{\sqrt{\frac{7676 - 100}{24}}}{5}$ | $= \frac{\sqrt{\frac{7633 - 635}{24}}}{5}$ |
| $= \frac{\sqrt{254.3}}{5}$ | $= \frac{\sqrt{315.7}}{5}$ | $= \frac{\sqrt{291.6}}{5}$ |
| $= 3.19$ | $= 3.55$ | $= 3.42$ |

Calculations of t :-

$$t = \frac{\bar{D}}{S_{\bar{D}}}$$

| Objective Test | Essay Test | Combined Test |
|---|---|---|
| $t = \frac{5.20}{3.19}$ | $t = \frac{2.00}{3.55}$ | $t = \frac{5.02}{3.42}$ |
| $= 1.63$ | $= 0.56$ | $= 1.47$ |

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