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COMMUNITY COLLEGE STUDENTS' ACHIEVEMENT AND ATTITUDE CHANGE IN A LECTURE ONLY, LECTURE-LABORATORY APPROACH TO GENERAL EDUCATION BIOLOGICAL SCIENCE COURSES

by

Donald Hood Dickinson

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF EDUCATION

in

Curriculum Development and Supervision
(Science Education)

UTAH STATE UNIVERSITY
Logan, Utah

1975

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Donald H. Dickinson

Donald Hood Dickinson

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ABSTRACT

A Comparison of Community College Students' Achievement and Attitude Changes in a Lecture-Only, Lecture-Laboratory, Lecture-Recitation Approach to General Education Biological Science Courses

by

Donald H. Dickinson, Doctor of Education

Utah State University, 1975

Major Professor: Dr. Walter L. Saunders
Department: Secondary Education

Student achievement and attitude changes toward science resulting from three different approaches used in teaching introductory general education biology at Diablo Valley Community College in Pleasant Hill, California, were compared. The three teaching approaches used were the lecture-only, lecture-laboratory and lecture-recitation.

The sample was composed of 129 students enrolled in Biology 101 and 102 at Diablo Valley Community College during fall semester 1974-75. Forty-three students comprised the control group taught by the lecture-only method. Forty-three students comprised the experimental group taught by the lecture-laboratory method. Forty-three students comprised a second experimental group taught by the lecture-recitation method.

Student achievement was measured using two subject matter achievement tests. One test was the Nelson Biology Test consisting of 65 multiple-choice items. A reliability coefficient of .93 was established using the Kuder Richardson Formula 20. A second achievement test consisting of 100 multiple-choice questions was constructed by the investigator. A reliability coefficient of .89 was established using the Kuder Richardson Formula 20. Student attitude change toward science was measured using a Scientific Attitude Inventory constructed by Richard Moore at Temple University. A reliability coefficient of .73 was established using the Kuder Richardson Formula 20.

Analysis of covariance was used to compare mean posttest scores for the three groups involved in each hypothesis. The Scheffé Test was used to make comparisons between pairs of group mean posttest scores. At the .05 level of significance, it was found that (1) students taught by the lecture-laboratory method had higher mean achievement scores than students taught by the lecture-only method when measured by either the Nelson Biology Test or the teacher-made test, (2) students taught by the lecture-laboratory method did not have significantly different mean achievement scores on the Nelson Biology Test than students taught by the lecture-recitation method, (3) students taught by the lecture-recitation method did not have significantly different mean achievement scores on the Nelson Biology Test or the teacher-made test than students taught by the lecture-only method when SCAT scores were used as the covariate, (4) students taught by the lecture-laboratory method had significantly higher mean achievement scores on the teacher-made test than

students in the lecture-recitation group when SCAT scores were used as the covariate, (5) student attitudes toward science were not significantly different for the students taught by the lecture-laboratory method than for students taught by the lecture-recitation method as measured by the Scientific Attitude Inventory, and (6) student attitudes toward science were changed more favorably by the lecture-laboratory and lecture-recitation methods than by the lecture-only method as measured by the Scientific Attitude Inventory.

The results of this study suggest that students benefit when they experience a personal involvement with biological materials and laboratory equipment in investigating principles taught in the lecture portion of the course. The personal hands-on experience in designing and carrying out investigations in the laboratory helps students to more closely identify with the biology course and the work of the biologist. Results also suggest that students benefit by the extra time offered by the laboratory experience. Students achieve more and indicate a more favorable change in attitude toward science upon completion of the lecture-laboratory course than do students completing the lecture-only course or the lecture-recitation course.

(126 pages)

INTRODUCTION

Statement of the problem

Introductory Biology students at Diablo Valley Community College have the option of enrolling in Biology 101, a lecture-only course, or Biology 102, a lecture-laboratory course. Students enrolled in Biology 102 during 1972-73 had higher mean scores on biology mid-term and final exams and more frequently said they enjoyed biology than did students enrolled in Biology 101. Instructors at the college have frequently asked themselves whether the laboratory as a teaching strategy improves student achievement on course examinations as well as student attitude towards biology, and whether any improvement in achievement on course examinations and attitude towards biology is due to the additional experiences students have in the lecture-laboratory course.

There has long been concern with the value of a laboratory experience in the teaching of science. Cunningham (1946) suggested that a closer look at general education science courses should be taken to see if the lecture-demonstration method is as effective as the individual laboratory method. This suggestion was based on his review of research going back to 1920.

More recently, Thornton (1972) stated that biologists have reason to believe that, properly used, the laboratory experience offers one of the best environments we have for meeting the educational needs which are now

so apparent. This kind of belief is widely prevalent in the science education literature and tends to influence decisions in curriculum planning.

In the Fifty-ninth Yearbook of the Study of Education, Rethinking Science Education, further support for providing laboratory experience and a new focus are found:

> Changing conceptions of the values and purposes of science teaching have tended toward an increasing emphasis upon laboratory work. The nature of the scientific enterprise is found in the methods by which problems are attacked. Therefore, more attention should be directed to the purposes or methods of seeking answers in the laboratory rather than putting so much stress on finding exact answers. More time should be spent by students in developing insights as to how data may be processed and predictions made from them. (p. 334)

Although the importance of laboratory participation has been widely emphasized, research findings on the effectiveness of such experiences remain inconclusive. Over the years many comparative studies have been conducted comparing lecture-demonstration groups with those having lecture-laboratory. Most of the studies dealing with the laboratory experience failed to establish the effectiveness of the method. Perhaps the reason for the inconclusiveness of these studies had to do with the measures of student achievement. The tests measuring student achievement were found by Brandwein, Watson, and Blackwood (1958) to be designed to test only textbook knowledge. Tests are needed that will evaluate both textbook knowledge and such laboratory outcomes as the ability to select and design appropriate equipment, to observe closely, to appraise results, to apply statistical analyses, to describe graphically and interpret data.

Furthermore, Cunningham (1946) suggested that these earlier studies, i.e., the studies comparing nonlaboratory or demonstration groups with those having laboratory, suffer from problems in design and inadequate statistical treatment; thus they fail to test properly the worth of the laboratory method of teaching science.

The majority of comparative studies focusing on the merits of the laboratory in science teaching have compared lecture-laboratory with lecture-demonstration methods in junior and senior high schools. There is a lakc of research comparing student achievement and attitude changes in lecture-only and lecture with laboratory biology courses in the community college.

Careful study of the results of laboratory work, individual or in small groups, is especially important at this time (Watson, 1963). To provide time, space, and materials for laboratory work is expensive. Laboratory work is also costly in student and instructor time.

The two reasons for this study were, (1) that there is a lack of studies comparing student achievement and attitude changes with lecture-only and lecture-laboratory classes in community college general introductory biology, and (2) those studies that have been done on the value of laboratory experience in the teaching of science are of poor design and lack adequate statistical treatment.

Purpose

The purpose of this investigation was to compare student achievement and attitude changes toward science resulting from two different approaches

used in teaching introductory general education biology in the community college. The two approaches were the lecture-only and the lecture-laboratory methods of teaching biology. A third approach, lecture-recitation was added for the purpose of controlling for instruction time (see pages 15 and 16 for detailed discussion).

Objectives

The specific objectives of this study were:

1. to compare the subject matter knowledge of the control (lecture-only) and experimental (lecture-laboratory and lecture-recitation) groups as measured by the Nelson Biology Test,
2. to compare the subject matter knowledge of the control and experimental groups as measured by a teacher-made multiple-choice achievement test, and
3. to compare the attitude changes toward science that occur during the semester the control and experimental groups are enrolled in Biology 101 and 102 as measured by the Scientific Attitude Inventory.

Hypotheses

The following hypotheses were tested:

There will be no statistically significant ($P = .05$) difference in the adjusted mean posttest scores obtained by:

1. students in the control and experimental groups on the Nelson Biology Test when the covariate is Nelson Biology pretest scores,
2. students in the control and experimental groups on the Nelson Biology Test when the covariate is the School and College Ability Test (SCAT) scores,
3. students in the control and experimental groups on a teacher-made multiple-choice subject matter achievement test when the covariate is pretest scores on the teacher-made achievement test,
4. students in the control and experimental groups on a teacher-made multiple-choice subject matter achievement test when the covariate is the SCAT scores,
5. students in the control and experimental groups on a Scientific Sttitude Inventory (SAI) when the covariate is SAI pretest scores, and
6. students in the control and experimental groups on a Scientific Attitude Inventory when the covariate is SCAT scores.

REVIEW OF RELATED RESEARCH

No studies were found in the literature specifically comparing community college student achievement and attitude changes in biology courses taught by a lecture-only with biology courses taught by a lecture-laboratory method. One study compared college student achievement in a lecture-only physics course with those in a lecture-laboratory physics course (Kruglak, 1953). Two different achievement tests were used: a mechanics theory test and a test designed to measure a knowledge of facts, principles, and applications of elementary mechanics. Kruglak reported no significant difference in mean scores on either the mechanics theory test or the knowledge test. He did, however, report that students receiving laboratory instruction performed better on tests designed to measure laboratory outcomes, but did not indicate whether or not the difference was statistically significant.

The research dealing with the lecture-laboratory method of teaching science has concentrated on comparing this method with the lecture-demonstration method. Cunningham (1948) reviewed the research from 1918 to 1946 dealing with the lecture-laboratory versus the lecture-demonstration method of teaching science. Eighteen master's theses, six doctor's dissertations, and ten articles published in professional journals were summarized. Twenty of the studies produced results favoring the lecture-demonstration method; six favored the lecture-laboratory method; and two reported no difference.

According to Cunningham (1946), these earlier studies often left much to be desired in the way of design and statistical treatment of the data.

Bradley (1968) reported findings supporting those of Cunningham (1946). He noted in his review of the literature that investigators of the lecture-laboratory method versus the lecture-demonstration method of teaching science had come to a variety of conclusions. Bradley (1968, p. 62) quoted Barnard as concluding:

> (1) the lecture-laboratory method has statistically significant advantages over the lecture-demonstration method with respect to achievement on a test dealing with scientific ideas, (2) the lecture-laboratory method has statistically significant advantages over the lecture-demonstration method with respect to achievement on a test covering certain abilities in problem solving.

Bradley (1968, p. 65) reported that Knox found the lecture-laboratory method to be superior for "inferior" students and the lecture-demonstration method to be superior for "better" students. Bradley (1968, p. 65) further reported that White found no statistically significant difference between the lecture-laboratory and the lecture-demonstration methods. Bradley did not report what dependent variables White used.

Watson (1963) reviewed the research from 1946 to 1958 dealing with the impact of laboratory work on science students. He (Watson, 1963, p. 1043) stated the following:

> The whole area seems still open for investigation. The hypotheses to be examined should come from a careful analysis of the important operations of science which can be illustrated and practiced in the laboratory, and they should be operationally explicit.

Schefler (1965) reviewed more recent research (1950-1962) concerning the lecture-laboratory approach versus the lecture-demonstration approach. He reported a definite need for more research and conducted a study comparing the lecture-laboratory with the lecture-demonstration method of teaching biology to college freshman. Schefler (1965) reported no significant difference in achievement scores on the Test of Understanding Science (TOUS) for students taught by the lecture-demonstration method. The TOUS test measures the subject's knowledge of the nature, processes, and limitations of science.

Gunsch (1972) compared student achievement and attitude changes toward science resulting from the lecture-laboratory and lecture-demonstration method of teaching college physical science to general education students. He reported finding a significant difference in scores on instructor prepared achievement tests and on The Scientific Attitude Inventory for students taught with lecture-laboratory and students taught with the lecture-demonstration methods. His conclusions were that students having the laboratory experience had more improved attitudes toward science and were better able to understand science concepts, ideas, and principles.

McKeachie (1963, p. 1144) reported the following regarding comparisons between laboratory teaching and other methods:

> Information cannot usually be obtained, however, by direct experience as rapidly as it can from abstractions presented orally or in print. Films or demonstrations may also short-cut some of the trial and error of the laboratory. Thus, one would not expect laboratory teaching to have any advantage over other methods in amount of information learned. Rather we might expect the differences to be revealed in retention, in ability to apply learning, or

> in actual skill in observations or manipulation of materials. Unfortunately, little research has attempted to tease out these special types of outcomes. If these special types of outcomes are unmeasured, a finding of no difference in effectiveness between laboratory and other methods of instruction is also meaningless since there is little reason to expect laboratory teaching to be effective in simple communication of information.

In summary, no studies were found in the literature comparing community college student achievement and attitude changes in biology courses taught by the lecture-only and lecture-laboratory method. The research dealing with the lecture-laboratory method of teaching science has concentrated on comparing this method with the lecture-demonstration method and a discrepancy exists in the conclusions reported. The one study comparing college student achievement in a lecture-only with a lecture-laboratory course was reported by Kruglak (1953) He found no significant difference in mean scores on tests designed to measure physics theory and knowledge, although students receiving laboratory instruction did better on tests designed to measure laboratory outcomes. There is a lack of research comparing community college student achievement and attitude changes in biology courses taught by the lecture-only and lecture-laboratory method. Likewise a discrepancy exists in the findings reported in the related research and studies are needed to deal with this problem.

PROCEDURES

Population and sample

It was anticipated that 1,000 students would enroll in the introductory general education biology courses (Biology 101 and 102) during the 1974-75 school year at Diablo Valley College, Pleasant Hill, California. This community college of 9,200 students is located in the central part of Contra Costa County, a lower-middle to lower-upper class ($10,000-$100,000 household income) area. Many of the cities and unincorporated urban areas in this part of the county (Danville, Walnut Creek, Orinda, Lafayette, Pleasant Hill and Concord) are referred to as "bedroom communities" indicating that people commute to work from the suburbs to, in this case, Oakland, San Francisco, and industrial areas along the river front.

Enrollment records at the college indicate that 60 percent of the students plan to go on to 4-year colleges and universities. Many will not do so. The rest of the students plan to complete a vocational program, terminating after earning an A.A. degree, or are taking course work for personal enrichment.

Biology 101 and 102 are 1-semester courses. This study was conducted during the fall semester 1974, and the accessible population consisted of 500 students--the usual course enrollment. A sample comprised of 150 students was randomly selected from the 500 to participate in the study.

Fifty were taught by the lecture-only method (Group A), 50 were taught by the lecture-laboratory method (Group B), and 50 were taught by the lecture-recitation method (Group C).

The community college student

The student body of the community college differs in composition from any stereotype of the college student (Thornton, 1972). The range of student abilities and goals is greater in the community college than in the 4-year college and university where admission policies are more selective. There is the "average" student who is not sure he can succeed at the university; there is the "bright" one who can not afford to leave home and a job to go away to college; there is the "poor" student (educationally handicapped) who lacks even the basic learning skills but who recognizes the importance of preparing for a career; and there is the student from the minority group who sees the community college as an opportunity to place him or her in a position of more equal footing for desired job placement. Finally there is the housewife who seeks cultural enrichment and the technologically obsolete family man who wants job retraining. The composition of the community college student body makes developing a biology course of instruction and choosing appropriate teaching strategies a formidable task.

Selected characteristics of biology students

The investigator conducted a survey by questionnaire (see Appendix A) of 575 students enrolled in Biology 101 and 102 at Diablo Valley Community

College during the spring semester 1974. The survey identified the following characteristics of Biology 101 and 102 students: 10 percent of the Biology 101 students and 12 percent of the Biology 102 students had taken no high school biology; 10 percent of the Biology 101 students and 10 percent of the Biology 102 students had taken a high school biology course having no laboratory instruction. The male-female ratio was 48 to 52 in Biology 101 and 39 to 61 in Biology 102; 58 percent of the Biology 101 students were employed part or full time and 62 percent of the Biology 102 students were employed part or full time; and finally 42 percent of the Biology 101 students reported having a good experience in high school biology while 53 percent of the Biology 102 students reported having a good experience in high school biology (see Table 1).

Nature of Biology 101 and 102:
Principles of Biology

Biology 101, Principles of Biology, is a 3-semester credit general education course taught at Diablo Valley Community College. It is a prerequisite for all the biology courses taught in the biology department. The course consists of three 50-minute periods per week. Biology 102 has the same lecture component as Biology 101 and in addition has a 2 1/2 hour laboratory (1 credit) meeting once per week. The lecture topics for Biology 101 and 102 include the following:

1. Science and its Methods
2. Searching for Order in the Living World
3. Cells: The Basic Units

Table 1. Selected characteristics of biology students enrolled in Biology 101 and 102 spring semester, 1974

Characteristics	Biology 101 (Lecture-only)		Biology 102 (Lecture-Laboratory)	
	No.	Percent	No.	Percent
No High School Biology	50	12.5	18	10.28
High School Biology--No Laboratory	38	9.5	19	10.86
High School Biology with Laboratory Bad Experience	34	8.5	7	4.0
High School Biology with Laboratory Tolerable Experience	103	25.75	38	22.3
High School Biology with Laboratory Good Experience	172	43.0	92	52.57
Males Enrolled	192	48.0	68	38.7
Females Enrolled	208	52.0	107	61.3
Students Employed	228	57.7	109	62.2

4. What are Living Things Made of?
5. Matter, Energy and Feeding Relationships
6. Matter and Energy, Cycle and Flow
7. How are Cells and Organisms Reproduced?
8. Genetics: How are Traits Transmitted?
9. Genetics: How are Genes Expressed as Traits?
10. Growth and Development
11. How are Organisms Regulated?
12. Hormones and Human Reproduction
13. Animal Behavior
14. Homeostasis in Ecosystems: Changing Populations
15. Homeostasis in Ecosystems: Habitats and Organisms
16. What is the Process of Evolution?

These lecture periods are intended to explain and develop principles of biology. The text used was Life and Patterns of Order by Steyaert (1972).

Design

This study compares the lecture-only with the lecture-laboratory method of teaching biology.

Students in Group A (control group) were taught by the lecture-only method. For Group A the class activities consisted of lectures, discussions, films, reading assignments, and lecture-slide presentations.

Students in Group B (experimental group) were taught by the lecture-laboratory method. The class activities for the lecture portion were identical with those of the control group. The laboratory portion consisted of lecture and discussion as well as group and individual laboratory work. Individuals were encouraged to investigate a research problem using the processes of science.

Becuase the lecture-only course provides students 3 hours of instruction per week, while the lecture-laboratory course gives students 6 hours of instruction, a third group taught by a lecture-recitation method and having 6 hours per week of instruction, but no laboratory, was added to control for instruction time--this was Group C (experimental group).

The recitation portion of the lecture-recitation course consisted of discussion of material presented in lecture, student reports on current biological issues, viewing films over the topics covered in lecture, demonstration of difficult concepts presented in the lecture, and a few opportunities to do "cook book" laboratory exercises such as looking at prepared slides under the microscope and models of plant and animal parts.

The experimental design was the pretest-posttest control-group model suggested by Campbell and Stanely (1963). The design may be designated:

R	O_1		O_2	(Lecture-only--Group A)
R	O_3	X_1	O_4	(Lecture-laboratory--Group B)
R	O_5	X_2	O_6	(Lecture-recitation--Group C)

The experimental variable, X_1, will be laboratory instruction. Recitation used to control for the instruction time of the laboratory treatment, is indicated by X_2.

Three instructors (the investigator and two others) participated in the study. Two of the instructors, the investigator and one other team-taught the lecture section (Figure 1). This large lecture section consisted of 250 students, including the 50 lecture-laboratory, 50 lecture-recitation, and 50 lecture-only students participating in the study. The three instructors taught sections of the laboratory and the recitation to students from the lecture-laboratory and lecture-recitation groups (Figure 1).

Instrumentation

To measure student achievement and attitude changes toward science resulting from the three methods of teaching the introductroy general education biology courses, the Nelson Biology Test, a teacher-made multiple choice achievement test, and the Scientific Attitude Inventory were used.

Horton (1957) in his review of the Nelson Biology Test, described it as having been developed primarily to measure understanding and the ability to apply knowledge in the interpretation of situations and the solution of problems. Testing of ability to recall minute, isolation facts has been minimized. Rather the student is given an opportunity to demonstrate how well he can discern relationships between what he has learned and the world of living things which he encounters every day.

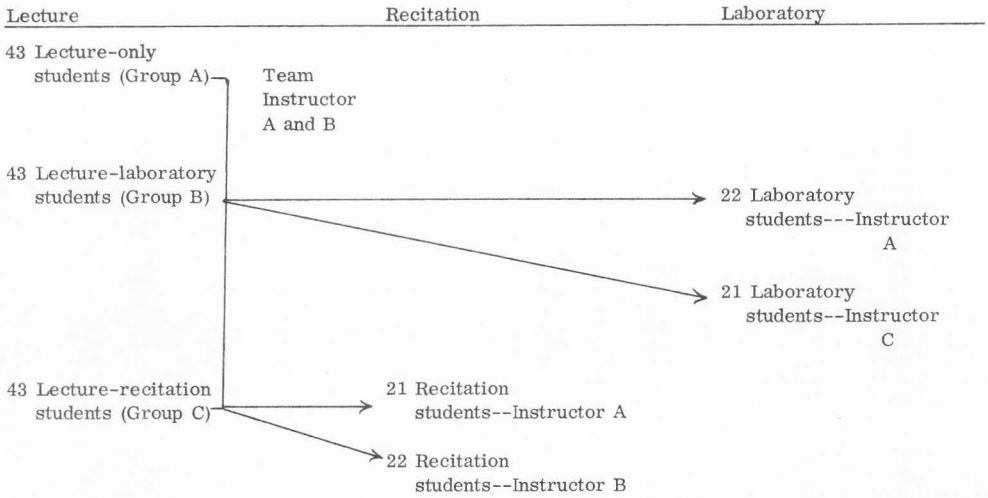

Figure 1. Instructional groups with instructor and by method of instruction.

The objectives of the Biology 101 and 102 courses at Diablo Valley College emphasize increasing the student's ability to apply knowledge in interpreting data and solving problems. The program de-emphasizes memorization of isolated facts.

Each of the two forms of the Nelson Biology Test consists of 65 multiple-choice items. Burros (1972) cites Novak (1968, pp. 269-270) regarding the revised (1965) Nelson Biology Test:

> The reliabilities provided in the manual show a general range of r=.89 to r=.92 for various schools in the standardization group. . . . The Nelson Biology Test has been the best single test available for a wide variety of research applications at the high school and elementary college level. The revised Nelson Biology Test undoubtedly will continue to be one of the most widely used and widely cited reference standards for pupil achievement in biology.

The reliabilities were established using the split-half method. The normative group consisted of 4,993 students in 63 schools representing 27 states throughout the country.

The investigator established reliability on the Nelson Biology Test for a sample in this study using both the split-half method and the Kuder-Richardson Formula 20. The split-half method produced r=.95 and the Kuder-Richardson Formula gave a r=.93.

A multiple-choice biology test was constructed (see Appendix C) using a test item source book titled Testing and Evaluation in the Biological Sciences (Commission on Undergraduate Education in the Biological Sciences, 1968). Items were selected that best represent the content of Biology 101 and 102. To insure a proportionate representation of content covered and to

evaluate student achievement at various levels of the cognitive domain, a content analysis chart was used to tally selected items. The summary of this analysis is shown in Figure 2. This test drew on items selected to test for analysis, synthesis, evaluation; and such laboratory outcomes as interpreting data and using and analyzing statistics--areas not covered by the Nelson Biology Test. Test reliability was established by using the Kuder-Richardson Formula 20. A reliability coefficient of .89 was obtained.

The Scientific Attitude Inventory was constructed and evaluated by Richard Moore at Temple University in 1969. He reported a reliability coefficient of .934 using the test-retest method. The inventory was field tested to demonstrate its construct validity (Moore, 1970). Moore did not report the procedure followed to demonstrate construct validity. The reliability of the Scientific Attitude Inventory for the sample of students in this study was established by using the Kuder-Richardson Formula 20. A reliability coefficient of .73 was obtained. Borg (1973) states that the Kuder-Richardson Formula 30 produces a lower reliability coefficient than other methods of estimating reliability. This might explain part of the reason for the difference in the values of r as reported by Moore and that found by the investigator in this study.

Analysis

Analysis of covariance was used to compare the three group's mean posttest scores for each of the three instruments. Two analyses were

CHART OF SPECIFICATIONS FOR A BIOLOGICAL EXAMINATION							
BEHAVIORAL OBJECTIVES	Cognitive Domain	INTELLECTUAL SKILLS AND ABILITIES					
CONTENT AREAS	1. Knowledge	2. Comprehension	3. Application	4. Analysis	5. Synthesis	6. Evaluation	Total
1. Energetics and Metabolism	. . . .	. . . .	. . . .	. .			14
2. Form-Function	. . .	. . . .	. . . .	. .			13
3. Behavior	. . . .	. . . .	. . . .	. .		. .	16
4. Genetics	. . . . . .	. . .	. . . .	. .		.	16
5. Reproduction and Development	. . . . .	. . . .	. . .		.		13
6. Systematics	. .						2
7. Evaluation	. . . .	. . . .	.				9
8. Organism-Environment	. . . . .	. . . . . .	.				12
9. History-Philosophy-Methodology	. . .	.				.	5
TOTAL							100

Figure 2. Content analysis of teacher-made achievement test.

conducted on each hypothesis. One analysis used School and College Ability Test (SCAT) scores as a covariate. The other analysis used pretest scores as a covariate. The Scheffé Test was used to make comparisons between pairs of group means.

FINDINGS

The findings are based on student achievement and changes in student's attitude toward science resulting from three different approaches used in teaching introductory general education biology at Diablo Valley Community College. The three approaches were the lecture-only, the lecture-laboratory, and the lecture-recitation. Student achievement was based on the results of an investigator-made multiple-choice achievement test and the Nelson Biology Test. Changes in student attitude were based on the results of the Scientific Attitude Inventory.

Statistical treatment of data

Hypotheses were tested using analysis of covariance to compare groups on mean posttest scores for each of the test instruments used. Covariance Analysis permits adjustment of the mean scores on the posttest measure to compensate for group differences found on pretest measures.

Following the analysis of covariance the Scheffé Test was used to make comparisons between pairs of group means. Differences were determined to be significant when the difference value was as great or greater than the Scheffé d value.

For each hypothesis the covariate means (pretest or SCAT Test means), treatment means (posttest means), and adjusted means are presented,

followed by a covariant analysis of the data and finally the difference in group means.

Hypothesis 1. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on the Nelson Biology Test when the covariate is Nelson Biology Test pretest scores.

The mean scores and the adjusted mean scores on the Nelson Biology Test for the three groups are shown in Table 2.

Table 2. Pretest, posttest, and adjusted means on the Nelson Biology Test for the three groups

Group	Pretest Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	29.58	40.56	40.55
Group B Lecture-Laboratory	30.60	46.14	45.38
Group C Lecture-Recitation	28.51	44.44	45.21

Table 3 presents the F-ratio for Hypothesis 1.

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 1 is rejected.

Table 3. Analysis of covariance on the mean posttest scores for the three groups on the Nelson Biology Test

Source of Variance	Adjusted Sum of Squares: X	df	Variance Estimates	F-ratio
Between Groups	647.312	2	323.656	5.227
Within Groups	7739.27	125	61.942	
Total	8386.582			

Table 4 presents the Scheffé "d" value for Hypothesis 1.

The difference in group means between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group means between Group A (lecture-only) and Group C (lecture-recitation) was significant at the P = .05 level. The difference in group means between Group B (lecture-laboratory) and Group C (lecture-recitation) was not significant at the P = .05 level.

Hypothesis 2. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on the Nelson Biology Test when the covariate is SCAT scores.

The mean SCAT scores, the mean posttest scores on the Nelson Biology Test and adjusted mean scores are presented in Table 5.

Table 6 presents the F-ratio for Hypothesis 6.

Table 4. Difference in adjusted group mean scores on the Nelson Biology Test when the covariate is pretest scores on the Nelson Biology Test

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	45.38		4.20
Group A Lecture-Only	-40.55		
Difference between mean scores	4.83	Significant	
Group C Lecture-Recitation	45.21		
Group A Lecture-Only	-40.55		
Difference between mean scores	4.66	Significant	
Group B Lecture-Laboratory	45.38		
Group C	-45.21		
Difference between mean scores	.17	Not significant	

Table 5. SCAT scores, posttest, and adjusted mean scores on the Nelson Biology Test for the three groups

Group	SCAT Score Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	64.44	40.28	41.59
Group B Lecture-Laboratory	68.77	46.28	45.55
Group C Lecture-Recitation	67.95	44.44	43.99

Table 6. Analysis of covariance on the mean posttest scores for the three groups on the Nelson Biology Test

Source of Variance	Adjusted Sum of Squares	df	Variance Estimates	F-ratio
Between Groups	647.31	2	323.65	5.23
Within Groups	7739.27	125	61.94	
Total	8386.58			

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 2 is rejected.

Table 7 presents the Scheffé "d" value for Hypothesis 2.

Table 7. Difference in adjusted group mean scores on the Nelson Biology Test when the covariate is SCAT scores

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	45.44		3.479
Group A Lecture-Only	-41.59		
Difference between mean scores	3.96	Significant	
Group C Lecture-Recitation	43.99		
Group A	-41.59		
Difference between mean scores	2.40	Not significant	
Group B Lecture-Laboratory	45.55		
Group C Lecture-Recitation	-43.99		
Difference between mean scores	1.56	Not significant	

The difference in group mean scores between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group mean scores between Group C (lecture-recitation) and Group A (lecture-only) was not significant at the P = .05 level. The difference in group mean scores between Group A (lecture-only) and Group C (lecture-recitation) was not significant at the P = .05 level. The difference in group means between Group B (lecture-laboratory) and Group C (lecture-recitation) was not significant at the P = .05 level.

Hypothesis 3. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on a teacher-made multiple-choice subject matter achievement test when the covariate is pretest scores on the teacher-made achievement test.

Table 8 presents the mean pretest scores, the mean posttest scores and the adjusted mean scores on the teacher-made achievement test.

Table 9 presents the F-ratio for Hypothesis 3.

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 3 is rejected.

Table 10 presents the Scheffé "d" value for Hypothesis 3.

The difference in group mean scores between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group mean scores between Group C (lecture-recitation) and Group A (lecture-only) was not significant at the P = .05 level. The difference

Table 8. Pretest, posttest, and adjusted mean scores on a teacher-made test for the three groups

Group	Pretest Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	40.77	56.32	55.97
Group B Lecture-Laboratory	40.63	63.81	63.55
Group C Lecture-Recitation	39.30	58.42	59.03

Table 9. Analysis of covariance on the mean posttest scores for the three groups on the teacher-made test

Source of Variance	Adjusted Sum of Squares	df	Variance Estimates	F-ratio
Between Groups	12320.4	2	625.392	7.062
Within Groups	11069.6	125	88.557	
Total	33390.0			

Table 10. Difference in adjusted group mean scores on the teacher-made test when the covariate is pretest scores

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	63.55		5.03
Group A Lecture-Only	-55.97		
Difference between mean scores	7.58	Significant	
Group C Lecture-Recitation	59.03		
Group A Lecture-Only	-55.97		
Differences between mean scores	3.06	Not significant	
Group B Lecture-Laboratory	63.55		
Group C Lecture-Recitation	-59.03		
Difference between mean scores	4.52	Not significant	

in group mean scores between Group B (lecture-laboratory) and Group C (lecture-recitation) was not significant at the P = .05 level.

Hypothesis 4. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on a teacher-made multiple choice subject

matter achievement test when the covariate is pretest scores on the teacher-made achievement test.

Table 11 presents the mean SCAT scores, the mean posttest scores and the adjusted mean scores on the teacher-made achievement test.

Table 12 presents the F-ratio for Hypothesis 3.

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 4 is rejected.

Table 13 presents the Scheffé "d" value for Hypothesis 4.

The difference in group mean scores between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group mean scores between Group C (lecture-recitation) and Group A (lecture-only) was not significant at the P = .05 level. The difference in group means between Group B (lecture-laboratory) and Group C (lecture-recitation) was significant at the P = .05 level.

Hypothesis 5. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on a Scientific Attitude Inventory when the covariate is SAI pretest scores.

Table 14 presents the mean scores for the three groups and the adjusted mean scores.

Table 15 presents the F-ratio for Hypothesis 5.

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 5 is rejected.

Table 11. SCAT, posttest, and adjusted mean scores on a teacher-made test for the three groups

Group	SCAT Score Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	64.30	56.32	57.563
Group B Lecture-Laboratory	68.76	63.81	63.000
Group C Lecture-Recitation	67.95	58.42	57.986

Table 12. Analysis of covariance on the mean posttest scores for the three groups on the teacher-made test

Source of Variance	Adjusted Sum of Squares	df	Variance Estimates	F-ratio
Between Groups	9528.8	2	392.053	5.6041
Within Groups	8744.7	125	69.957	
Total	18273.5			

Table 13. Difference in adjusted group mean scores on the teacher-made test when the covariate is SCAT scores

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	63.01		4.47
Group A Lecture-Only	-57.56		
Difference between mean scores	5.45	Significant	
Group C Lecture-Recitation	57.98		
Group A Lecture-Only	-57.56		
Difference between mean scores	.42	Not significant	
Group B Lecture-Laboratory	63.01		
Group C Lecture-Recitation	-57.98		
Difference between mean scores	5.03	Significant	

Table 14. Pretest, posttest, and adjusted mean on the Scientific Attitude Inventory for the three groups

Group	Pretest Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	118.14	121.65	123.56
Group B Lecture-Laboratory	122.02	129.65	129.29
Group C Lecture-Recitation	124.09	131.84	130.28

Table 15. Analysis of covariance on the mean posttest scores for the three groups on the Scientific Attitude Inventory

Source of Variance	Adjusted Sum of Squares	df	Variance Estimates	F-ratio
Between Groups	647.31	2	323.65	5.227
Within Groups	7739.27	125	61.94	
Total	8386.58			

Table 16 presents the Scheffé "d" value for Hypothesis 5.

Table 16. Difference in adjusted group mean scores on the Scientific Attitude Inventory when the covariate is SAI scores

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	129.29		5.48
Group A Lecture-Only	-123.58		
Difference between mean scores	5.71	Significant	
Group C Lecture-Recitation	130.28		
Group A Lecture-Only	-123.58		
Difference between mean scores	6.70	Significant	
Group C Lecture-Recitation	130.28		
Group B Lecture-Laboratory	-129.29		
Difference between mean scores	.99	Not significant	

The difference in group means between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group means between Group A (lecture-only) and Group C (lecture-recitation) was significant at the P = .05 level. The difference in group means between Group C (lecture-recitation) and Group B (lecture-laboratory) was not significant at P = .05 level.

Hypothesis 6. There will be no statistically significant (P = .05) difference in the adjusted mean posttest scores obtained by students in Groups A, B, and C on a Scientific Attitude Inventory when the covariate is SCAT scores.

Table 17 presents the mean scores and the adjusted mean scores for the three groups.

Table 18 presents the F-ratio for Hypothesis 6.

The F-ratio is statistically significant at the .05 level for 125 degrees of freedom. Hypothesis 6 is rejected.

Table 19 presents the Scheffé "d" value for Hypothesis 6.

The difference in group means between Group A (lecture-only) and Group B (lecture-laboratory) was significant at the P = .05 level. The difference in group means between Group A (lecture-only) and Group C (lecture-recitation) was significant at the P = .05 level. The difference in group means between Group B (lecture-laboratory) and Group C (lecture-recitation) was not significant at the P = .05 level.

Table 17. SCAT scores, posttest, and adjusted mean scores on the Scientific Attitude Inventory for the three groups

Group	SCAT Test Mean Y	Posttest Mean X	Adjusted Mean X''
Group A Lecture-Only	64.30	120.79	121.499
Group B Lecture-Laboratory	68.51	129.651	129.221
Group C Lecture-Recitation	67.95	131.674	131.396

Table 18. Analysis of covariance on the mean posttest scores for the three groups on the Scientific Attitude Inventory

Source of Variance	Adjusted Sum of Squares: X	df	Variance Estimates	F-ratio
Between Groups	2881.75	2	1149.97	6.247
Within Groups	25566.2	125	184.06	
Total	28448.0			

Table 19. Difference in adjusted group mean scores on the Scientific Attitude Inventory when the covariate is SCAT scores

Group	Adjusted X Mean		d value
Group B Lecture-Laboratory	129.221		7.612
Group A Lecture-Only	-121.499		
Difference between mean scores	7.722	Significant	
Group C Lecture-Recitation	131.396		
Group A Lecture-Only	-121.499		
Difference between mean scores	9.897	Significant	
Group C Lecture-Recitation	131.396		
Group B Lecture-Laboratory	-129.221		
Difference between mean scores	2.175	Not significant	

Analyses of the data

The analyses of the data lead to the following findings:

1. Mean scores on the Scientific Attitude Inventory were significantly higher (P = .05) for students in the lecture-laboratory and lecture-recitation groups than for students in the lecture-only group when

SAI pretest scores were used as a covariate in covariate analysis of the data.

2. Mean scores on the Scientific Attitude Inventory were not significantly different IP = .05) for students in the lecture-laboratory group than for the lecture-recitation group when either SAI pretest scores or SCAT scores were used as a covariate in covariant analysis of the data.

3. Mean scores on the Scientific Attitude Inventory were significantly higher (P = .05) for students in the lecture-laboratory group than for students in the lecture-only group when SCAT scores were used as a covariate in covariant analysis of the data.

4. Mean scores on the Scientific Attitude Inventory were not significantly different IP = .05) for students in the lecture-recitation group than for students in the lecture-only group and SCAT scores were used as a covariate in covariant analysis of the data.

5. Mean achievement scores for students taught by the lecture-laboratory method were significantly higher (P = .05) than mean achievement scores of students taught by the lecture-only method when measured by the teacher-made biology achievement test and either SCAT scores or pretest scores were used as a covariate in covariant analysis of the data.

6. Mean achievement scores for students taught by the lecture-laboratory method were not significantly different (P = .05) than

mean achievement scores of students taught by the lecture-recitation method when measured by the teacher-made biology achievement test and pretest scores were used as a covariate in covariant analysis of the data.

7. Mean achievement scores for students taught by the lecture-laboratory method were significantly higher (P = .05) than mean achievement scores of students taught by the lecture-recitation method when measured by the teacher-made biology achievement test and SCAT scores were used as a covariate in covariant analysis of the data.

8. Mean achievement scores for students taught by the lecture-recitation method were not significantly different (P = .05) than mean achievement scores of students taught by the lecture-only method when measured by a teacher-made biology achievement test and either pretest scores or SCAT scores were used as a covariate in covariant analysis of the data.

9. Mean achievement scores for students taught by the lecture-laboratory method were significantly higher (P = .05) than mean achievement scores of students taught by the lecture-only method when measured by the Nelson Biology Test and either pretest scores or SCAT scores were used as a covariate in covariant analysis of the data.

10. Mean achievement scores for students taught by the lecture-laboratory method were not significantly different (P = .05) than mean achievement scores of students taught by the lecture-recitation method when measured by the Nelson Biology Test and either pretest scores or SCAT scores were used as a covariate in covariant analysis of the data.

11. Mean achievement scores for students taught by the lecture-recitation method were significantly higher (P = .05) than mean achievement scores of students taught by the lecture-only method when measured by the Nelson Biology Test and pretest scores were used as the covariate in covariant analysis of the data.

12. Mean achievement scores for students taught by the lecture-recitation method were not significantly different (P = .05) than mean achievement scores of students taught by the lecture-only method when measured by the Nelson Biology Test and SCAT acores were used as the covariate in covariant analysis of the data.

Interpretation of findings

1. Higher mean scores on the Scientific Attitude posttest were evidenced in Group B (lecture-laboratory) and Group C (lecture-recitation) than in Group A (lecture-only). Students in all groups attended the same biology lectures. In addition, Group B attended a weekly 3 hour laboratory class and

Group C attended a weekly 3 hour recitation class. The additional time would not account for the higher mean Scientific Attitude Inventory scores, however, the experiences within the laboratory or recitation session could have an effect on attitudes toward science.

Students in lecture-laboratory conducted investigations and used some of the methods and equipment of the biologist in the laboratory. Students in this group were exposed to teacher instruction in procedures for laboratory activities, and teacher-student discussions of laboratory exercises. Those experiences appear to have had an effect on scientific attitudes and produced changes in responses to items on the Scientific Attitude Inventory in the categories of emotional and positive attitudes that brought about the higher mean scientific attitude scores.

2. Students in Group C (lecture-recitation) were shown film on topics covered in lecture, discussed material covered in lecture, observed demonstrations of difficult concepts covered in lecture and participated in a few "cook book" laboratory exercises such as viewing prepared slides. The lecture-recitation groups' experiences produced higher mean scores in scientific attitude than those of students with the lecture-only experience. The lecture-recitation group did not have mean scientific attitude scores significantly different at $P = .05$ than those of the lecture-laboratory group. This would indicate that the lecture-laboratory and lecture-recitation methods of teaching introductory biology at the community college were similarly effective in bringing about changes in scientific attitude scores.

3. Higher mean scores on the Nelson Biology posttest were evidenced by students taught by the lecture-laboratory and lecture-recitation methods than students taught by the lecture-only method. No significant difference was found when the lecture-laboratory group was compared with the lecture-recitation group. When Nelson Biology posttest scores were adjusted using SCAT scores, students taught by the lecture-recitation method did not have mean achievement scores on the Nelson Biology Test significantly different at the $P = .05$ level than students taught by the lecture-only method. Differences in ability scores on the SCAT test were greater than differences in pretest scores between the lecture-only and the lecture-recitation. The experimental findings suggest that the lecture-laboratory method increased student performance on the Nelson Biology Test (a biology achievement test) more than did either the lecture-recitation method or the lecture-only method of teaching biology. Findings further suggest that the additional instruction time and additional student involvement in learning activities provided in the laboratory and recitation session bring increased performance on achievement tests and enhance retention of knowledge and reasoning skills for the duration of the course.

4. Students in the lecture-laboratory group performed better on the teacher-made achievement test than students in the lecture-only or lecture-recitation groups when achievement scores were adjusted to School and College Ability Tests (SCAT) scores.

The lecture-laboratory students participated more actively in course related work. All students designed an investigation related to one of the major topics of the course. The involvement increased students' overall participation in the course work. The instructors participating in the study agreed that these students had better attendance, asked more questions and seemed more anxious to read in the journals having articles in areas related to course content. All students were asked to read and report on at least five journal articles. At the end of the semester teacher records indicated that only 35 percent (15 out of 43) of the lecture-only group had completed the assignment, while 72 percent (31 out of 43) of the lecture-laboratory group had completed the assignment.

The lecture-laboratory students had a significantly $P = .05$ higher mean achievement scores on the teacher-made posttest than did students in the lecture-only group.

Students in the lecture-recitation group had a higher adjusted mean achievement score on the teacher-made test than did the students in the lecture-only group. The difference in the mean scores for these two groups was not significant at the $P = .05$ level. The extra class time and the activities in the lecture-recitation may account for their slightly higher mean achievement scores.

During a 3-week period that the lecture-laboratory group was involved in a plant growth and development block, a team spirit became evident. Teams within the laboratory class became competitive in gathering and organizing

data. Students met outside of the classroom and exchanged data and worked together in interpreting their findings. The increased interest in the course may well have had carry over into the reading of the text and preparing for examinations. Ten of the 43 students in the lecture-laboratory group wrote an unsolicited positive comment about what the course meant to them on their final examination paper. No such comments appeared on the final exam papers of members of the other two groups.

SUMMARY AND CONCLUSIONS

Three methods of teaching introductory biology at Diablo Valley Community College were compared for their effects on student achievement and changes in attitude toward science. The three methods compared were the lecture-only, lecture-laboratory and lecture-recitation. The lecture-only and lecture-laboratory methods are used in teaching the introductory biology courses at Diablo Valley Community College. Because the lecture-only course gives students 3 hours of instruction per week while the lecture-laboratory course gives students 6 hours of instruction, a third method having 6 hours per week of instruction, but no laboratory was added to control for instruction time.

Student achievement was measured by two objective tests. One was the Nelson Biology Test consisting of 65 questions including multiple-choice, matching, and true false items. The other achievement test was an investigator-made multiple-choice test consisting of 100 multiple-choice items.

Student attitude toward science was measured by a scientific attitude inventory. The scientific attitude inventory consisted of 60 questions dealing with the intellectual attitudes, emotional attitudes, positive attitudes and negative attitudes (see Appendix B).

In order to look at similarities and differences between students in Biology 101 (lecture-only) and students in Biology 102 (lecture-recitation), a

survey of 575 Diablo Valley Community College students enrolled in Biology 101 (lecture-only) and Biology 102 (lecture-laboratory) was conducted during the spring semester 1974.

The survey identified the following characteristics of Biology 101 and 102 students: 10 percent of the Biology 101 students and 10 percent of the Biology 102 students had taken a high school biology course having no laboratory instruction. The male-female ratio was 48 to 52 in Biology 101 and 39 to 61 in Biology 102; 58 percent of the Biology 101 students were employed part or full time and 62 percent of the 102 students were employed part or full time; and finally 42 percent of the Biology 101 students reported having a good experience in high school biology while 52 percent of the Biology 102 students reported having a good experience in high school biology (see Table 1).

Six hypotheses stated in the null form were tested.

There will be no statistically significant ($P = .05$) difference in the adjusted mean posttest scores obtained by:

1. students in Groups A (lecture-only), B (lecture-laboratory) and C (lecture-recitation) on the Nelson Biology Test when the covariate is Nelson Biology pretest scores,
2. students in Groups A (lecture-only), B (lecture-laboratory) and C (lecture-recitation) on the Nelson Biology Test when the covariate is the School and College Ability Test (SCAT) scores,

3. students in Groups A (lecture-only), B (lecture-laboratory), and C (lecture-recitation) on a teacher-made multiple-choice subject matter achievement test,
4. students in the control and experimental groups on a teacher-made multiple-choice subject matter achievement test when the covariate is the SCAT scores,
5. students in the control and experimental groups on a Scientific Attitude Inventory (SAI) when the covariate is SAI pretest scores, and
6. students in the control and experimental groups on a Scientific Attitude Inventory when the covariate is SCAT scores.

Significance was determined by using analysis of covariance. All six hypotheses were rejected at the .05 level of significance.

To determine which groups were significantly different from each other, the Scheffé Test was used.

Students in the lecture-laboratory had higher mean scores on the achievement tests than did students in the lecture-recitation and lecture-only groups.

Students in the lecture-only group had lower scientific attitude scores and lower achievement scores than either the lecture-laboratory or the lecture-recitation group.

Students in the lecture-recitation group had higher scientific attitude scores than students in the lecture-only group.

No significant difference in attitude towards science was found between the lecture-laboratory group and the lecture-recitation group.

The lecture-laboratory students had significantly higher mean biology achievement scores than lecture-recitation or lecture-only students.

The data from this investigation support the following conclusions:

1. Diablo Valley Community College introductory biology students have more positive attitudes towards science and perform better on biology achievement tests when they experience a personal involvement with biological materials and laboratory equipment in investigating principles taught in the lecture portion of the course.
2. The personal hand-on experience in designing and conducting investigations in the laboratory helps students of introductory biology at Diablo Valley Community College to more closely identify with the biology course and the work of the biologist.
3. The lecture-recitation method and the lecture-laboratory method were both more effective methods of instruction than the lecture-only method.

Implications

The results of this study indicate that students at Diablo Valley Community College enrolled in Biology 102, a lecture-laboratory course, can be taught more effectively than students at this college enrolled in Biology 101,

a lecture-only course. Results indicate that students benefit by the extra time and personal involvement offered by the laboratory and recitation experience. Students achieve more and indicate a more favorable change in attitude toward science upon completion of the Biology 102 course (lecture-laboratory) than do students completing the Biology 101 (lecture-only) course.

Suggestions for further study

Results of this study indicate that the lecture-laboratory course improves student achievement and attitudes towards science. On the basis of the experience gained during the study, the following additional studies are recommended:

1. A replication study using the same format as this study to see if the same results would be obtained with Diablo Valley College students enrolled in the spring semester.
2. A study similar to this study but having several small lecture classes (40 to 45 students) taught by the same lecture team and half of the classes getting only the lecture while the remaining classes have the added laboratory period or recitation period.
3. A follow-up investigation to determine what the retention of biology knowledge tested for in this study will be after a longer period of time.

4. A follow-up investigation to determine if the favorable attitude gain is maintained after a longer period of time.
5. A study comparing the lecture-recitation with the lecture-laboratory method of teaching introductory general biology.

Other concluding remarks

Although data provided by the two subject matter achievement tests and the attitude inventory did not indicate significant differences between the lecture-laboratory and lecture-recitation groups, casual observations did suggest differences in behavior between the two groups.

During the 3-week period that the lecture-laboratory group was involved in a plant growth and development block, a team spirit became evident. Teams within the laboratory class became competitive in gathering and organizing data. Students met outside the classroom and exchanged data and worked together in interpreting their findings. The increased interest in the course may well have had carry over into the reading of the text and preparing for examinations. Ten of the 43 students in the lecture-laboratory group wrote an unsolicited positive comment about what the course meant to them on their final examination paper. No such comments appeared on the final examination papers of members of the other two groups.

During the semester students the three different groups were asked to read a minimum of five articles found in scientific journals and turn in a summary card on each article. Most of the students in the lecture-laboratory

Table 20. Summary of the hypotheses

Hypotheses	Findings	Difference in Adjusted Mean Scores Between Group Pairs (significant difference at P=.05) Group A (Lecture-Only) Group B (Lecture-Lab.)	 Group A (Lecture-Only) Group C (Lecture-Recit.)	 Group B(Lecture-Lab.) Group C (lecture-Recit.)
There will be no statistically significant (P=.05) difference in the adjusted mean post-test scores obtained by students in groups A (lecture-only), B (lecture-laboratory) and C (lecture-recitation) on the:				
I. Nelson Biology Test when the covariate is pre-test scores on the Nelson Biology Test.	rejected	significant Group B $\bar{X}$= 45.38 Group A $\bar{X}$= 40.55 Difference 4.83 Scheffe' "d" value 4.20	significant Group C $\bar{X}$= 45.21 Group A $\bar{X}$= 40.55 Difference 4.66 Scheffe' "d" value 4.20	not significant Group B $\bar{X}$= 45.38 Group C $\bar{X}$= 45.21 Difference .17 Scheffe' "d" value 4.20
II. Nelson Biology Test when the covariate is SCAT scores.	rejected	significant Group B $\bar{X}$= 45.55 Group A $\bar{X}$= 41.59 Difference 3.96 Scheffe' "d" value 3.48	not significant Group C $\bar{X}$= 43.99 Group A $\bar{X}$= 41.59 Difference 2.40 Scheffe' "d" value 3.48	not significant Group B $\bar{X}$= 45.55 Group C $\bar{X}$= 43.99 Difference 1.56 Scheffe' "d" value 3.48
III. Teacher-made achievement test when the covariate is pre-test scores on teacher-made test.	rejected	significant Group B $\bar{X}$= 63.55 Group A $\bar{X}$= 55.97 Difference 7.58 Scheffe' "d" value 5.03	not significant Group C $\bar{X}$= 59.03 Group A $\bar{X}$= 55.97 Difference 3.06 Scheffe' "d" value 5.03	not significant Group B $\bar{X}$= 63.55 Group C $\bar{X}$= 59.03 Difference 4.52 Scheffe' "d" value 5.03
IV. Teacher-made achievement test when the covariate is SCAT scores.	rejected	significant Group B $\bar{X}$= 63.01 Group A $\bar{X}$= 57.56 Difference 5.45 Scheffe' "d" value 4.47	not significant Group C $\bar{X}$= 57.98 Group A $\bar{X}$= 57.56 Difference .42 Scheffe' "d" value 4.47	significant Group B $\bar{X}$= 63.01 Group C $\bar{X}$= 57.98 Difference 5.03 Scheffe' "d" value 4.47
V. Scientific Attitude Inventory when the covariate is SIA pre-test scores.	rejected	significant Group B $\bar{X}$= 129.29 Group A $\bar{X}$= 123.58 Difference 6.02 Scheffe' "d" value 5.48	significant Group C $\bar{X}$= 130.28 Group A $\bar{X}$= 123.58 Difference 6.70 Scheffe' "d" value 5.48	not significant Group C $\bar{X}$= 130.28 Group B $\bar{X}$= 129.29 Difference .99 Scheffe' "d" value 5.48
VI. Scientific Attitude Inventory when the covariate is SCAT scores.	rejected	significant Group B $\bar{X}$= 129.22 Group A $\bar{X}$= 121.49 Difference 7.72 Scheffe' "d" value 7.61	significant Group C $\bar{X}$= 131.39 Group A $\bar{X}$= 121.49 Difference 9.89 Scheffe' "d" value 7.61	not significant Group C $\bar{X}$=131.39 Group B $\bar{X}$=129.22 Difference 2.17 Scheffe' "d" value 7.61

group did turn in a minimum of five reading cards. Students in the lecture-recitation and lecture-only groups turned in fewer journal summaries. The closer relationship with the instructor and the other students experienced by the lecture-laboratory group could account for the added motivation to become more involved in the course work. The test instruments used were not designed to measure knowledge gained through the outside readings and many of the laboratory outcomes in both the affective and cognitive domains.

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APPENDIXES

Appendix A: Questionnaires

STUDENT QUESTIONAIRE FOR BIOLOGY 101

1. Social Security number _ _ _ / _ _ / _ _ _ _

2. When you enrolled for Biology 101 did you understand that it was a lecture course without a laboratory experience?
Yes ___ No ___

3. Have you had a high school biology course?
Yes ___ No ___

4. If you had a high school biology course did it provide you with a laboratory experience?
Yes ___ No ___

5. I you had a high school biology course with a laboratory, how would you rate your laboratory experience? Check the one that best describes your experience.

A. A good experience ___
B. A tolerable experience ___
C. A bad experience ___

6. In a brief statement tell why you chose to enroll for Biology 101 and not Biology 102.

7. Major field of study if known _____

8. Male ___ Single ___
Female ___ Married ___

9. How many semester credits are you carrying this term? ___

10. Are you employed?
Yes ___ No ___

11. If employed how many hours a week do you work, Monday through Friday? _____

STUDENT QUESTIONAIRE FOR BIOLOGY 102

1. Social Security number _ _ / _ / _ _ _ _

2. When you enrolled for Biology 102 did you reason that taking the laboratory along with the lecture course would help you to gain more from the course?
   Yes ___ No ___

3. Have you had a high school biology course?
   Yes ___ No ___

4. If you had a high school biology course, did it provide you with a laboratory experience?
   Yes ___ No ___

5. If you had a high school biology course with a laboratory experience, how would you rate your expereince? Chech the one that best describes your experience.
   A. Tolerable ___
   B. A good experience ___
   C. A bad expereince ___

6. In a brief statement tell why you chose to enroll for Biology 102 and not Biology 101.

7. Major field of study if known _____

8. Male ___ Single ___
   Female ___ Married ___

9. How many semester credits are you carrying this term? ___

10. Are you employed?
    Yes ___ No ___

11. If employed how many hours a week do you work, Monday through Friday? _____

Biology 101 students' reasons for not enrolling in Biology 102 with laboratory	Number of Responses	Percent
1. Not enough time	97	24.25
2. Scheduling problem	64	16.0
3. Did not want lab	49	12.25
4. Fills G.E. Requirement for A.A. degree with lecture only class	44	11.0
5. Too hard, too much work	32	8.0
6. State college transfer requirement satisfied with lecture only course	24	6.0
7. Major does not require it	22	5.5
8. Have satisfied laboratory science requirement in another science course	16	4.0
9. Could not dissect animals	13	3.25
10. Only class open	12	3.0
11. Counselor advised taking course without laboratory	8	2.0
12. Did not know which course to enroll in	7	1.75
13. Prefer lecture to lecture laboratory	5	1.25
14. No biology background	3	.75
15. Repeat of high school biology laboratory	3	.75

Biology 102 students' reasons for wanting the lab with lecture	Number of Responses	Percent
1. Wanted a lab, like lab, enjoy lab, interest in lab	44	22
2. Helps me understand lecture material	41	20
3. Prep for major area or other biology courses	30	15
4. Gives me a more complete course	20	10
5. Transfer requirement	16	8
6. More units given	14	7
7. Prefer to learn with hands on experience	10	5
8. This college requires it for A.A. degree	9	4
9. Counselor advised me	8	4
10. Just enrolled	2	1
11. More variety	2	1
12. Benefits me	1	.5
13. Want to learn all I can	1	.5
14. Like Science	1	.5
15. Lab is easier	1	.5
16. No other class available	1	.5
17. Why not	1	.5

Appendix B: Scientific Attitude Inventory

Attitudes Assessed by the

SCIENTIFIC ATTITUDE INVENTORY

1-A The laws and/or theories of science are approximations of the truth and are subject to change. (7, 10, 23, 53, 56)

1-B The laws and/or theories of science represent unchangeable truths discovered through science. (12, 16, 22, 46, 54)

2-A Observation of natural phenomena is the basis of scientific explanation. Science is limited in that it can only a nswer questions about natural phenomena and sometimes it is not able to do that. (15, 19, 27, 29 and 52)

2-B The basis of scientific explaination is in authority. Science deals with all problems and it can provide correct answers to all questions. (2, 3, 11, 39, 43)

3-A To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence. (18, 25, 26, 37, 42)

3-B To operate in a scientific manner one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.

4-A Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects. (6, 32, 33, 34, 47)

4-B Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses. (14, 24, 41, 44, 50)

5-A Progress in science re quires public support in this age of science, therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultmately benefits from scientific work. (17, 28, 30, 40, 48)

5-B Public understanding of science would contribute nothing to the advancement of science or to human welfare, therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them. (9, 13, 31, 36, 58)

6-A Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work. (1, 45, 49, 55, 60)

6-B Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work. (20, 21, 35, 57, 59)

Statements 1-A through 3-B deal with Intellectual Attitudes.

Statements 4-A through 6-B deal with Emotional Attitudes.

All A statements are statements of positive attitudes toward science.

All B statements are statements of negative attitudes toward science.

Paired A and B statements are in opposition to each other.

WHAT IS YOUR ATTITUDE TOWARD SCIENCE?

(A Scientific Attitude Inventory)

There are some statements about science on the next few pages. Some statements are about the nature of science, some are about how scientists work. Some of these statements describe how you might feel about science. You may agree with some of the statements and you may disagree with others. That is exactly what you will be asked to do. By doing this, you will show your attitude toward science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree mildly or strongly. If you disagree, decide whether you disagree mildly or strongly. Then, find the number of that statement on the answer sheet, and blacken the space by the

1 if you agree strongly.

2 if you agree mildly.

3 if you disagree mildly.

4 if you disagree strongly.

Example:

00. I would like to have a lot of money.

00. 1 ▬ 2 ═ 3 ═ 4 ═

(The person who marked this example agrees strongly with the statement, "I would like to have a lot of money.")

Please respond to each statement and blacken only <u>one</u> space for each statement.

Please do not make any marks on this test booklet.

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WHAT IS YOUR ATTITUDE TOWARD SCIENCE?

1. I would enjoy studying science and using this knowledge in some scientific field.

2. Anything we need to know can be found out through science.

3. Scientific explanations can be made only by scientists.

4. Once they have developed a good theory, scientists must stick together to prevent others from saying it is wrong.

5. It is useless to listen to a new idea unless everybody agrees with the idea.

6. Science may be described as being primarily an idea-generating activity.

7. Scientists are always interested in improving their explanations of natural events.

8. If one scientist says a theory is true, all other scientists will believe him.

9. Science is so difficult that only highly trained scientists can understand it.

10. A useful scientific theory may not be entirely correct, but it is the best idea scientists have been able to think up.

11. We can always get answers to our questions by asking a scientist.

12. There are some things which are known by science to be absolutely true.

13. Most people are not able to understand the work of science.

14. Today's electric appliances are examples of the really valuable products of science.

15. Scientists cannot always find the answers to their questions.

16. When something is explained well, there is no reason to look for another explanation.

17. Most people are able to understand the work of science.

18. A scientific theory is no better than the objective observations upon which it is based.

19. Scientists believe that they can find explanations for what they observe by looking at natural phenomena.

20. The day after day search for scientific knowledge would become boring for me.

21. Scientific work would be too hard for me.

22. Scientists discover laws which tell us exactly what is going on in nature.

23. Scientific ideas may be said to undergo a process of evolution in their development.

24. The value of science lies in its usefulness in solving practical problems.

25. When one asks questions in science, he gets information by observing natural phenomena.

26. A good scientist doesn't have any ideas he is not willing to change.

27. Looking at natural phenomena is a most important source of scientific information.

28. Public understanding of science is necessary because scientific research requires financial support through the government.

29. Some questions cannot be answered by science.

30. Rapid progress in science requires public support.

31. Scientists do not need public support, they can get along quite well without it.

32. A scientist must be imaginative in developing ideas which explain natural events.

33. The value of science lies in its theoretical products.

34. Ideas are one of the more important products of science.

35. I do not want to be a scientist because it takes too much education.

36. There is no need for the public to understand science in order for scientific progress to occur.

37. When a scientist is shown enough evidence that one of his ideas is a poor one, he should change his idea.

38. All one has to do to learn to work in a scientific manner is to study the writings of great scientists.

39. Before one can do anything in science, he must study the writings of the great scientists.

40. People need to understand the nature of science because it has such a great affect upon their lives.

41. A major purpose of science is to produce new drugs and save lives.

42. One of the most important jobs of a scientist is to report exactly what his senses tell him.

43. If a scientist cannot answer a question, all he has to do is to ask another scientist.

44. An important purpose of science is to help man to live longer.

45. I would enjoy working with other scientists in an effort to solve scientific problems.

46. Scientific laws cannot be changed.

47. Science is devoted to describing how things happen.

48. Every citizen should understand science because we are living in an age of science.

49. I may not make many great discoveries, but working in science would still be interesting to me.

50. A major purpose of science is to help man live more comfortably.

51. Scientists should not criticize each other's work.

52. His senses are one of the most important tools a scientist has.

53. Scientists believe that nothing is known to be true with absolute certainty.

54. Scientific laws have been proven beyond all possible doubt.

55. I would like to work in a scientific field.

56. A new theory may be accepted when it can be shown to explain things as well as another theory.

57. Scientists do not have enough time for their families or for fun.

58. The products of scientific work are mainly useful to scientists, they are not very useful to the average person.

59. Scientists have to study too much and I would not want to be one for this reason.

60. Working in a laboratory would be an interesting way to earn a living.

Appendix C: Investigator-Constructed Multiple-Choice Subject Matter Test

BIOLOGY 101 & 102 PRETEST

1. To a living organism, which of the following has the greatest amount of available energy per molecule?
   A. ATP
   B. ADP
   C. AMP
   D. H_2O
   E. CO_2

2. It is possible for a redbud tree to produce flowers in the spring before it produces leaves because
   A. no energy is required for the production of flowers.
   B. redbud petals photosynthesize enough to furnish all the energy needed in flower formation.
   C. the redbud trees metabolize insects which are attracted to the flowers.
   D. photosynthesis in the new growth of redbud stems furnishes enough energy for flowering.
   E. stored food from the year before is metabolized to provide energy for flowering.

3. The use of energy entering an organism from the outside is 100% efficient in
   A. unicellular green plants only.
   B. all green plants.
   C. unicellular animals.
   D. bacteria.
   E. no organisms.

4. The greatest amount of energy used by a single type of human tissue is used by
   A. epithelial tissue.
   B. muscular tissue.
   C. nervous tissue.
   D. connective tissue.
   E. vascular tissue.

5. If the temperature of the chamber is lowered from 30° to 5° C the amount of heat given off by the mouse should
   A. decrease because the mouse will use heat given off in respiration in regulating its temperature.
   B. decrease because the mouse will move less thus using less energy and releasing less heat.
   C. increase because the mouse will burn more stored energy in order to regulate its temperature by shivering.
   D. increase because the mouse will move less thus having less heat available.
   E. remain the same, since the mouse regulates its temperature and thus the rate of respiration remains the same.

6. In an oak forest, the greatest amount of energy turnover is accomplished by the
   A. oaks.
   B. squirrels.
   C. hawks.
   D. fungi.
   E. bacteria.

7. Which of the following events in a vegetable garden is never directly affected by light?
   A. Seed germination
   B. Flowering
   C. Food manufacture
   D. Fertilization
   E. Transpiration

8. A theater audience applauds following a performance. The room immediately seems to become warmer. Which is probably the major reason for this change?
   A. This is a psychological effect--during the performance the audience ignores the heat.
   B. Body temperatures are lower during the performance due to inactivity.
   C. Everyone puts on his coat.
   D. Heat is released as a result of muscular activity and increased glucose oxidation.
   E. The lights are turned on, giving off heat.

9. Homeostosis is a function of:
   A. cells
   B. organisms
   C. populations
   D. eco systems
   E. all of these

10. During Priestley's day it was believed that the main function of photosynthesis was to purify the air. Our present-day view regarding the significance of photosynthesis is that it
    A. converts light energy into chemical energy.
    B. creates usable energy.
    C. "fixes" CO_2 into carbohydrates.
    D. reverses the action of respiration.
    E. splits water, releasing O_2.

11. Within the cell, the site of respiration is the
    A. Golgi bodies.
    B. ribosomes.
    C. mitochondria.
    D. nucleus.
    E. nucleolus.

12. The "first step" in photosynthesis is the
    A. formation of ATP.
    B. ionization of water.
    C. excitement of an electron of chlorophyll a by a photon of light.
    D. attachment of CO_2 to a 5-carbon sugar.
    E. joining of two 3-carbon compounds to form glucose.

13. Every ecosystem must have a continual external source of
    A. living adult organisms.
    B. plant spores.
    C. bacteria.
    D. oxygen.
    E. energy.

14. Which of the following does the nucleus not contain?
    A. chromosomes
    B. nucleolus
    C. genes
    D. mitochondria and chloroplasts

15. A functional advantage of having human testes in a scrotum rather in the abdomen is:
    A. less corwding of the intestine.
    B. shorter sperm ducts.
    C. more accessible communication with the anus.
    D. more direct blood supply.
    E. lower temperature.

16. In humans, the male and female reproductive tracts differ in that the male tract:
    A. is open to the abdominal cavity.
    B. is single through part of its extent.
    C. is paired through part of its extent.
    D. has part of its extent in common with the urinary tract.
    E. carries gametes.

17. Hormone A causing an increase in the production of hormone B which in turn increases the production of hormone C which causes a decrease in hormone A is an example of:
    A. positive feedback.
    B. negative feedback.
    C. positive then negative feedback
    D. negative then positive feedback

18. The cell is separated into compartments by:
    A. membranes.
    B. solid walls
    C. fibers
    D. no physical barrier.

19. Five events occurred in an algal cell:
    A. An enzyme was manufactured at a ribosome.
    B. Cellulose was deposited as a cell wall.
    C. Under the influence of DNA, a molecule of RNA was constructed.
    D. A carbohydrate polymer was formed.
    E. A nucleic acid migrated from nucleus to cytoplasm.

20. It is discovered that these five events constitute a cause-and-effect sequence. The order in which these events occurred is therefore
    A. D-B-A-C-E.
    B. E-C-D-A-B.
    C. B-A-D-E-C.
    D. A-C-E-D-B.
    E. C-E-A-D-B.

Items 21-23 are based on the following information about three new species of animals which fit into our existing classification system.

	I	II	III
Habitat is:	terrestrial	marine	terrestrial
Embryo develops in:	water	mother	egg
Skeleton is:	internal	internal	internal
Epidermis covered with:	slime or mucus	hair	scales
Mates:	in water	in water	on land

21. If we arrange the animals according to the proportion of yolk in their eggs, the most likely sequence (least to most yolk) is
    A. I, II, III.
    B. I, III, II.
    C. II, III, I.
    D. II, I, III.
    E. III, II, I.

22. Which animal(s) most likely has (have) gills at some stage in the life cycle?
    A. Species I only
    B. Species II only
    C. Species I and II only
    D. Species I and III only
    E. None of the above species

23. Which animal(s) is (are) probably dormant when the air temperature is below freezing?
    A. Species I only
    B. Species II only
    C. Species I and II only
    D. Species I and III only
    E. None of the above species

24. The principle of division of labor among members of a population is best illustrated by which of the following?
    A. A school of herring
    B. A nest of termites
    C. A pack of wolves
    D. A herd of elephants
    E. A grove of poplars

25. Which of the following is true of uracil?
    A. It is present in RNA by not DNA, and is a pyrimidine complementary to adenine.
    B. It is present in messenger RNA but not in transfer RNA and is a pyrimidine complementary to cytosine.
    C. It is present in transfer RNA but not messenger RNA and is a purine complementary to guanine.
    D. It is present in ribosomal RNA but not messenger RNA and is a purine complementary to thymine.
    E. It is present in messenger and transfer RNA but not ribosomal RNA and is a pyrimidine complementary to guanine.

26. Involuntary, unconscious activities are associated with the:
    A. central nervous system.
    B. autonomic nervous system.
    C. both of these.
    D. neither of these.

27. The area between two neurons is called the:
    A. axon.
    B. sensory.
    C. synapse.
    D. cell body.
    E. dendrite.

28. A stickleback fish vigorously attacks other sticklebacks near its nest, but the strength of the attack diminishes the further the fish is from its nest. This phenomenon is in accordance with
    A. heterozygosity.
    B. dominance hierarchies.
    C. social integration.
    D. territorial behavior.
    E. maintenance behavior.

29. The behavior pattern of a certain kind of crab is cyclic and concurrent with tidal cycles. If the crab is kept in a refrigerator for six hours, then restored to its usual temperature, its behavioral pattern is six hours out of phase with tidal cycles. The most likely of the following explanations of this is that
    A. cold anesthetizes a crab's central nervous system.
    B. complete darkness stops a crab's biological clock.
    C. crabs respond to no other external stimuli except light and heat.
    D. in winter, the moon is slightly slower in changing phases than in the summer.
    E. enzyme manufacture is at a standstill while the crab is being refrigerated.

30. A trained planarian, fed to an untrained planarian, transmits some of its behavioral characteristics. The mechanism of this transmission centers around a
    A. nucleic acid.
    B. protein.
    C. polysaccharide.
    D. lipoid.
    E. steroid.

31. Population growth pressure is a probable cause of which of the following?
    A. Genetic drift
    B. Production of sterile hybrids
    C. Ecological isolation
    D. Migration of lemmings
    E. Abiogenesis

32. According to recent findings, what appears to be the main purpose that motivates the male robin to sing?
    A. He thereby attracts the female of his choice.
    B. He consciously provides aesthetic beauty of sound in the world of nature.
    C. He proclaims to the world that he is happy.
    D. He thereby attempts to frighten away cats and other enemy species.
    E. He thereby warns other male robins to keep off his domain.

33. Cow A consistently threatens Cow B with impunity; Cow B always retreats without a fight. This is an example of
    A. dependent assortment.
    B. homozygous dominance.
    C. habituation.
    D. epimeletic behavior.
    E. dominance hierarchy.

34. A pairing of a new stimulus with an old one so that the new one elicits the same response as the old is called:
    A. habituation.
    B. classical conditioning.
    C. operant conditioning.
    D. imprinting.

35. Seasonal changes bring on display of breeding behavior in some birds and mammals. The mechanism of this effect involves especially
    A. thymic corpuscles.
    B. gustatory epithelium.
    C. Malpighian corpuscles.
    D. Islets of Langerhans.
    E. retinal rod cells.

36. The rank position of a dairy cow is largely a function of
    A. her seniority in the herd.
    B. the acreage allotted to the herd.
    C. the quality of the available forage.
    D. the number of cows in the herd.
    E. the breeds of cattle in the herd.

37. Animal behavior involves:
    A. only cells.
    B. only organisms.
    C. only ecosystems.
    D. all levels of organization.

38. Migratory behavior of temperate region birds is related to:
    A. length of day.
    B. nerve-hormone behavior.
    C. changes in sex organs.
    D. a and b
    E. a, b, and c

39. The submission of females in a male-female relationship tends to:
    A. inhibit aggressive behavior by the male.
    B. promote aggressive behavior by the male.
    C. has no effect on aggressive behavior of males.

40. Which of the following variables would be expected to correlate most highly with the peck order of a flock of chickens?
    A. Proportion of vitamins in the diet
    B. Color of the bird
    C. Quantity of certain endocrine secretions
    D. Thickness of the skin
    E. Deployment of nerve endings in the skin

41. A mature female and a mature male dove are separated in adjoining cages. The male displays. The female builds a nest and lays infertile eggs. What function of courtship is demonstrated?
    A. Orientation or bringing together of individuals
    B. Synchronization of release of gametes
    C. Indentification of sex
    D. Reproductive isolation or species identification
    E. Reduction of agressive behavior

42. The social structure of a bird flock concerned with relative dominance of its members is called the
    A. peck order.
    B. rassenkreis.
    C. overburden.
    D. nasute.
    E. axial gradient.

43. Bird song commonly expresses
    A. hunger.
    B. pugnacity.
    C. euphoria.
    D. territoriality.
    E. courtship.

44. Social hierarchy results in
    A. increased competition for mates.
    B. increased competition for food.
    C. reduced energy expenditure.
    D. reduced dominance.
    E. reduced gene frequencies.

45. A mature, mated pair of ringneck doves in breeding condition are separated in adjoining cages. On being placed together what would be the expected behavioral sequence of the male if mating would take place.

I. bow-coo	A. II, I, IV, III
II. hop-charge	B. I, II, III, IV
III. nest-call	C. IV, I, II, III
IV. preening	D. III, II, I, IV

46. A brown-eyed man whose mother was blue-eyed marries a brown-eyed woman whose father had blue eyes. What are the chances that this couple will have a blue-eyed child?
    A. 1/4
    B. 1/2
    C. 3/4
    D. none of these

47. If we crossed a pink 4 o'clock flower with a white 4 o'clock flower we should expect:
    A. all pink offspring.
    B. 1/2 pink, 1/2 white offspring.
    C. all white offspring.
    D. 1/4 red, 1/2 pink, 1/4 white offspring.

48. The haploid part of the life cycle of animals are the:
    A. spores.
    B. vegetative units.
    C. adults.
    D. gametes.
    E. none of these.

49. It is suggested that Queen Victoria of England possessed a gene for hemophilia. This would indicate that
    A. her father also possessed this gene.
    B. hemophilia would occur in more of her male descendants than of her female descendants.
    C. all of her daughters must have carried the gene for hemophilia.
    D. all of her sons must have had a gène for hemophilia.
    E. Victoria herself was hemophilic.

50. There is a breed of cats in which genes for black or white hair color do not show dominance or recessiveness. If a cat carrying only black hair color genes is bred to a cat carrying only white hair genes all of the offspring have grey hair. If two of these grey cats reproduce, the theoretical progeny ratio would be
    A. all gray.
    B. either all black or all white.
    C. 1/2 black, 1/2 white.
    D. 1/2 gray, 1/4 white, 1/4 black.
    E. 1/3 each of black, white, and gray individuals.

51. Slight differences in identical twins supports the hypothesis that
    A. dominance may be incomplete.
    B. genetic traits are influenced by many genes.
    C. single genes may produce multiple effects.
    D. the environment affects the expression of genetic characteristics.
    E. they developed from separate fertilized eggs.

52. A male must receive his Y chromosome from:
    A. his father.
    B. his mother.
    C. either his father or mother.
    D. neither.

53. You are asked to classify cell organelles on the basis of their principal functions. One category you erect is for organelles whose chief function concerns cell division. Which of the following is the most likely representative of this category?
A. Lysosome
B. Mitochondrion
C. Centriole
D. Ribosome
E. Golgi Body

54. A poultry farmer discovers that a recessive mutation has occurred in his flock, greatly increasing egg production. He would like to distribute this throughout his flock as quickly as possible. Which of the following would do this best?
A. Use a high-production hen as a brooder to hatch as many eggs as she can
B. Interbreed both male and female offspring of high-production hen
C. Breed sons of a high-production hen with heterozygous hens
D. Interbreed heterozygous hens and heterozygous cocks.
E. Submit the unfertilized eggs of a high-production hen to artificial parthenogenesis.

55. A population of wild rats obeying the Hardy-Weinberg Law with respect to coat color would be expected to
A. increase the proportion of dominant phenotypes.
B. increase the proportion of heterozygotes.
C. increase the proportion of homozygous recessives.
D. maintain a constant proportion of dominant to recessive genes.
E. eliminate heterozygosity.

56. Matching:

Genotype_____	A. The appearance of the organism
Phenotype_____	B. Allele expressed when heterozygous
Dominance_____	C. An example is AA
Recessiveness__	D. That portion of chromosome that determines a genetic trait
Gene_____	
Homozygous_____	E. None of these

57. Testosterone is a hormone secreted by:
A. cells of the testes.
B. follicle.
C. corpus luteum.
D. anterior lobe of the pituitary gland.

58. Ovulation in human occurs:
A. during menstruation.
B. approximately mid-way between menstrual periods.
C. immediately following menstruation.
D. just previous to menstruation.

59. The hormone levels in the menstrual cycle are controlled by the:
    A. uterus.
    B. ovaries.
    C. uterus and the ovaries.
    D. uterus, ovaries and pituitary gland.

60. Progesterone is often described as the pregnancy hormone because it:
    A. prepares the uterus to receive the egg.
    B. stimulates ovulation.
    C. stimulates estrogen production.
    D. stimulates the corpus luteum.

61. Secondary sex characteristics in the female are maintained by:
    A. androgens.
    B. estrogens.
    C. gonadotropic hormones.
    D. oxytoxin.

62. In mammals, fertilization usually takes place in the:
    A. ovary.
    B. uterus.
    C. vagina.
    D. oviduct.

63. The secondary sexual characteristics of male mammals are under the direct control of:
    A. FSH.
    B. LH.
    C. estrogen.
    D. testosterone.

64. LH stimulates the cells of the testes to:
    A. degenerate.
    B. product sperms.
    C. secrete testosterone.
    D. secrete estrogen.
    E. none of these.

65. FSH causes:
    A. sperm production.
    B. activity of testis cells.
    C. no activity in the testes.
    D. secondary sexual characteristics in the male.

66. That system originating from the embryonic ectoderm is the
    A. digestive system.
    B. muscular system.
    C. nervous system.
    D. circulatory system.
    E. endocrine system.

67. Propose a procedure to determine the final fate of a cell on the outer surface of a frog blastula.

68. If the generation of time of a certain species of bacteria is 20 minutes, how many bacteria will be present after two hours, if we start with one bacterium?
A. 12
B. 32
C. 40
D. 64
E. 128

69. "Year after year, men cruising timber or hunting deer in the Blue Mountains of eastern Oregon had come back with the same story. Near the little hamlet of Kamela, they had often heard a faraway tinkling, a ghostly bell ringing. No one was ever able to track down the strange sound.. It would fade away in the sighs of the wind through the big pines. Skeptics accused the men of hearing things.

"Last week, slashing a right-of-way for a power line from Bonneville Dam, lumberjacks brought down a ponderosa pine. Tied by a shriveled leather thong, high in the treetop was the answer to the mystery of Kamela: a bronze cattle bell, inscribed with the date 1878. . . .The people of Kamela guessed that a pioneer had tied it to a sapling that grew in to a towering pine." (TIME Magazine.) Which of the following is the best appraisal of the concluding sentence in this report?
A. Logical--because a tree elongates from the ground up.
B. Logical--because this particular tree could have attained great height since 1878.
C. Illogical--because no one knows with certainty when the bell was tied to the sapling.
D. Illogical--because elongation occurs only in the region of meristematic cells.
E. There is no basis for appraising the concluding sentence of the report.

70. The procedure by which organisms are placed into categories based upon likenesses and differences caused by divergent evolution is called:
A. cataloguing.
B. classification.
C. categorizing.
D. systematizing.

71. Which ratio is constant for the members of species but varies widely between species?
    A. Adenine + thymine / cytosine + guanine
    B. Adenine + cytosine / thymine + guanine
    C. Adenine + guanine / cytosine + thymine
    D. Ribose + purine / deoxyribose + pyrmidine
    E. Purine + pyrimidine / ribose + deoxyribose

72. The development of large size in land plants is especially correlated with
    A. increased efficiency in asexual reproduction.
    B. insect pollination.
    C. specialization of vascular tissues.
    D. appearance of an electron transport system.
    E. development of a cambium.

73. The idea that the appendix in man will disappear because it is no longer used follows the ideas of:
    A. Lamarck.
    B. Linnaeus.
    C. Darwin.
    D. Hooke.

74. If life may come only from previously existing life, then:
    A. life must have originated by spontaneous generation many times.
    B. life has never begun.
    C. life begins through spontaneous generation whenever a new organism is formed through reproduction.
    D. life must have originated by spontaneous generation at least once.

75. The idea that the giraffe's neck became longer after many generations because of natural selection follows the ideas of:
    A. Lamarck.
    B. Linnaeus.
    C. Darwin.
    D. Hooke.

76. Selection pressures of the environment act directly on:
    A. genotype.
    B. phenotype.
    C. either genotype or phenotype.
    D. neither genotype nor phenotype.

77. Variations within populations arise from:
    A. only mutations.
    B. only sexual recombinations.
    C. both mutations and sexual recombinations.
    C. neither mutations nor sexual recombinations.

78. Which one of the following is not a requirement for the expression of the Hardy-Weinberg Law?
    A. no mutations of genes or chromosomes.
    B. no migration of types in or out of the population
    C. the population must be large
    D. the environment must favor at least one phenotype

79. New genes are added to the gene pool by:
    A. mutations only.
    B. migration only.
    C. either mutations or migrations.
    D. neither mutations nor migrations.

80. Which is most important in determining the direction of evolution of an animal species?
    A. High mutation rate for certain traits.
    B. Independent assortment and recombination of certain traits
    C. Selection of certain traits by environmental conditions
    D. The gradual change of certain traits by environmental conditions
    E. "An inner desire to survive in the face of change"

81. The sequence: willow--spruce--birch--maple represents a
    A. phylogenetic trend.
    B. food pyramid.
    C. plant succession.
    D. genetic drift.
    E. homeostatic community.

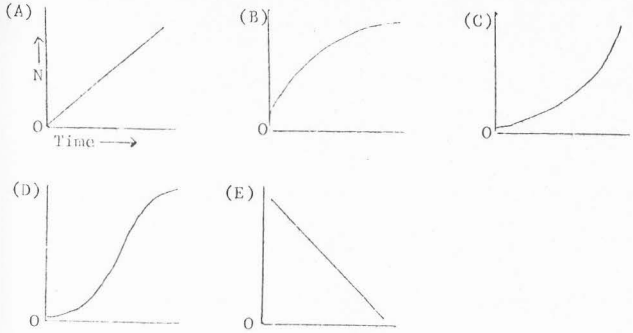
82. Match the organism or organisms with the life zone:

_____Zone 1 - splash zone	A. lined shore crab and Black Turban Snail
_____Zone 2 - high tide	
_____Zone 3 - mid tide	B. Sand "Fleas"
_____Zone 4 - low tide	C. Palm Tree Kelp and Sea Urchin
	D. Starfish and Barnacles

83. A stage in ecological succession in which organisms tolerate the conditions they create and a relatively stable homeostatic state is maintained is called:
    A. climax.
    B. pioneer.
    C. final.
    D. intermediate.

84. Which of the following is an ecological principle?
    A. Double limbs are mirror images of each other.
    B. Evolution is irreversible.
    C. All life arises from pre-existing life.
    D. Ontogeny recapitulates phylogeny.
    E. Animals living in colder climates have relatively smaller appendages than those living in warmer climates.

Items 85-87 are to interpreted in relation to the following graphs. For each item select the graph which best represents the data presented in the item.



85. Which figure best represents the population growth (total number) for an organism that reproduces by splitting in constant time intervals and without any death? (Let X-axis represent time and Y-axis represent population numbers on an exponential scale.)

86. Which figure best represents actual population growth (total number) of fruit flies in a jar closed with cheesecloth and well stocked with food? (Let X-axis represent time in days and Y-axis represent number of flies.)

87. Which best describes a self-contained spacecraft?
    A. Organ system
    B. Population
    C. Community
    D. Ecosystem
    E. Biosphere

88. In a certain ecosystem, field mice are preyed upon by snakes and hawks. The entrance of wild dogs into the system adds another predator on the mice. Of the following, the most likely short-term result of this addition is
    A. increase in snake population.
    B. tendency for hawks to prey on the dogs.
    C. extinction of the hawks.
    D. reduction in numbers of mice.
    E. migration of the hawks to another ecosystem.

89. A dog was kept in a room at a temperature of 40° C. for two weeks. At the end of that time, it was determined that the dog was sterile. The investigation proposed the hypothesis that the high temperature had caused the animal's sterility. In order to defend the hypothesis, the investigator should be able to show that
    A. the dog was homozygous for temperature sensitivity.
    B. the high temperature did not alter the dog's blood pressure.
    C. the dog was not sterile before the experimental period began.
    D. a cat kept in the same room did not become sterile.
    E. the dog's pituitary gland had not degenerated.

90. The group that serves as a reference in an experimental study is called the:
    A. control group.
    B. experimental group.
    C. validity group.
    D. study group.

91. In an experimental study, the group subjected to the factor under study is called the:
    A. control group.
    B. experimental group.
    C. validity group.
    D. study group.

92. A proposed pattern of order that has not been tested is called:
    A. hypothesis.
    B. law.
    C. theory.
    D. fact.

93. The purpose of controls in scientific experimentation is:
    A. provide a right answer.
    B. provide a frame of reference.
    C. provide data for hypotheses.
    D. provide evidence for a conclusion.
    E. provide a balance for the experiment.

94. The common immediate source of energy in cellular activity is
    A. DNA.
    B. RNA.
    C. ATP.
    D. NAD.
    E. FAD.

95. If Mr. and Mrs. Smith have two boys and one girl, the chances that the next child to be born will be a girl are:
    A. 1/2
    B. 1/4
    C. 1/3
    D. 3/4

96. Which represents the flow of energy?
    A. Sparrow--›seeds--›hawk--›bacteria
    B. Hawk-- seeds-- bacteria--›sparrow
    C. Seeds--› sparrow--›hawk--› bacteria
    D. Sparrow-- hawk--› bacteria--›seeds

97. Which of the following classes of vertebrates has <u>no</u> known representative which glides through the air on modified appendages and/or skin folds?
    A. Osteichthyes
    B. Amphibia
    C. Reptilia
    D. Aves
    E. Mammalia

98. The principal nucleic acid of which chromosomes are composed is
    A. DNA.
    B. ribosomal RNA.
    C. transfer RNA.
    D. messenger RNA
    E. uracil.

99. Reproductive cells that usually must fuse with other reproductive cells to form an offspring are called:
    A. spores
    B. vegetative units
    C. buds
    D. gametes

100. Modern species have evolved from:
    A. other species living today
    B. ancestral forms which are now extinct
    C. ancestors in a sequence resembling a straight-line ladder or scale
    D. other subspecies living today

Appendix D: Nelson Biology Test

NELSON BIOLOGY TEST—FORM E

[ ] 1 Characteristics of both plants and animals are found in –

[a] lichens
[b] liverworts
[c] euglena
[d] horsetails
[DK]

[ ] 2 In a balanced aquarium oxygen is provided by –

[e] snails
[f] green plants
[g] sunlight
[h] water
[DK]

[ ] 3 Which one of the following diseases might an individual contract from the food he has eaten?

[a] typhus fever
[b] anemia
[c] diabetes
[d] trichinosis
[DK]

[ ] 4 The balance of nature has been most seriously disturbed by –

[e] carnivorous animals
[f] civilized man
[g] insects
[h] bacteria and fungi
[DK]

[ ] 5 Which one of the following constitutes a food chain?

[a] milkweed–plant lice–spider–small bird–hawk
[b] grasshopper–wheat plant–mole–horse–whale
[c] mouse–rabbit–flea–woodchuck–snake
[d] corn–muskrat–bear–lion–deer
[DK]

[ ] 6 The presence of certain apparently useless structures in man's body, such as the appendix and the muscles in the outer ears, may be an indication that –

[e] man had remote ancestors who used these structures
[f] man has always been as he is today
[g] man can regenerate organs at will
[h] these structures have helped man to survive
[DK]

[ ] 7 Which of the following is an example of sexual reproduction?

[a] A mature paramecium divides into two offspring.
[b] A gardener plants pieces of potatoes containing "eyes" and later harvests a crop of potatoes.
[c] A fern plant produces many brown spores on the underside of the leaves. These spores give rise to young plants.
[d] A fish-hatchery worker pours some salmon milt into a jar of salmon eggs which later hatch into young salmon.
[DK]

[ ] 8 One of the most marked differences between animal cells and plant cells is that –

[e] plant cells have chromosomes
[f] animal cells ordinarily have a nucleus
[g] plant cells usually have thick, rigid walls
[h] animal cells contain protoplasm
[DK]

[ ] 9 Which one of the following is an example of a flowering plant?

[a] fern
[b] moss
[c] lichen
[d] corn
[DK]

[ ] 10 One of the most important functions served by root hairs is to –

[e] increase the plant's sensitivity to stimuli
[f] increase the root's total absorbing surface
[g] enable roots to penetrate deeper into soil
[h] increase the total food storage capacity of the root
[DK]

[ ] 11 A young man on an African safari was suddenly chased by a rhinoceros. He barely got into his truck when the rhino punched a hole in the side of the truck with the horn on its snout. The man's escape to cover was accelerated by a sudden secretion from which gland(s)?

[a] pituitary
[b] thyroid
[c] islets of the pancreas
[d] adrenal
[DK]

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NELSON BIOLOGY TEST—FORM E

For questions 12 through 16, read carefully the following account of the science methodology used by Pasteur in studying chicken cholera.

Pasteur, while studying chicken cholera, happened to inoculate some laboratory hens with an *old* culture of the disease rather than with the fresh material he ordinarily used. Instead of dying, as other chickens had when inoculated with a culture of cholera microbes, these hens became ill and then recovered. Some time later he re-inoculated these hens (which we will call Group A) with a fresh cholera culture. He had expected them to die, as chickens usually did when inoculated with deadly cholera microbes. To his surprise, however, these hens remained perfectly healthy.

He then used some of this same *fresh* culture to inoculate another group of healthy chickens that had never before been inoculated. (We will call these hens Group B.) Within a few days all Group B chickens were either dead or dying. Meanwhile the Group A chickens, which had received the same kind of deadly cholera microbes in their second inoculation, were running about as usual, suffering no ill effects.

Now what could have happened to these hens in Group A, Pasteur wondered, that enabled them to withstand a second inoculation of deadly cholera germs without even getting sick? He went about for days pondering this question. Then an idea occurred to him! Perhaps the old weakened culture, used in the first inoculation of the Group A hens, had stimulated the chickens' own bodies to produce something in the blood stream that would fight off any similar germs which might later get into the blood stream. He would find out!

Classify each of the questions 12 through 16 according to the following KEY:

KEY
- [e] A problem that Pasteur would investigate.
- [f] A hypothesis suggesting a possible solution to the problem.
- [g] A constant factor – the same for both Group A and Group B.
- [h] The variable being tested – not the same for Group A and Group B.
- [DK]

[ ] **12** An inoculation of an *old* culture of cholera microbes was given to the Group A chickens.

[ ] **13** What could have happened to the chickens in Group A that enabled them to withstand a second inoculation of deadly cholera germs without even getting sick?

[ ] **14** An inoculation of *fresh* deadly cholera microbes was given to all of the chickens used in the experiment.

[ ] **15** Perhaps the old weakened culture, used in the first inoculation of Group A chickens, had stimulated the chickens' own bodies to produce something in the blood stream that would fight off any similar germs which might later gain entrance into the body.

[ ] **16** Pasteur used the same kind of experimental animal throughout this series of experiments.

Questions 17 through 19 are based on the illustration of the stages in the life cycle of a moss plant shown below. For each question select the best answer.

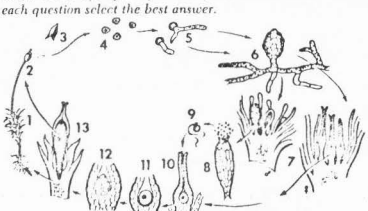

Diagram adapted from Pauli, Wolfgang G. *The World of Life*: Student's Manual. Boston: Houghton Mifflin Company, 1949, P. 19.

[ ] **17** Which of the above represents the male gamete?
[a] 3 [b] 4 [c] 5 [d] 9 [DK]

[ ] **18** Which of the above shows the 2*n* zygote?
[e] 6 [f] 11 [g] 10 [h] 8 [DK]

[ ] **19** The *n* or haploid chromosome number occurs in all *except* which one of the above?
[a] 2 [b] 4 [c] 5 [d] 9 [DK]

[ ] **20** The Mediterranean fruit fly has eight chromosomes in each of its body cells. The normal number of chromosomes in one of its mature sperm cells or egg cells would, therefore, be –
- [e] two
- [f] four
- [g] eight
- [h] sixteen
- [DK]

GO ON TO THE NEXT PAGE ►

NELSON BIOLOGY TEST—FORM E

[ ] **21** In a food web, certain organisms are regarded as decomposers, some as producers, others as primary consumers, and still others as secondary consumers. Which of the following would be classified as a secondary consumer?

[a] deer
[b] wolf
[c] rabbit
[d] mouse
[DK]

[ ] **22** A young plant vigorously growing near a window gradually bends toward the light because –

[e] the plant needs light to carry on photosynthesis
[f] the cells on the lighted side elongate faster than those on the shaded side
[g] the cells on the shaded side elongate faster than those on the lighted side
[h] stored radiant energy is being released as the plant grows
[DK]

[ ] **23** The cabin of a long distance space ship could be made into a balanced biome by making provision for growing algae in it. During a flight of a year's duration, the algae could do all of the following *except* –

[a] supply food for passengers
[b] remove carbon dioxide from the interior of the space ship
[c] utilize body wastes from passengers
[d] carry on photosynthesis in the absence of light
[DK]

[ ] **24** Two well-watered geranium plants, in sealed pots, were placed under two dry bell jars, X and Y. The leaves of the plant under Jar X were coated with vaseline on both upper and lower surfaces, while those of the plant under Jar Y were not coated. The two bell jars were then placed in bright sunlight for 8 hours. At the end of this time, what was the probable condition of the inside surface of the bell jars?

[e] Jar X showed more moisture than Jar Y.
[f] Jar X showed less moisture than Jar Y.
[g] Each jar was very moist with no noticeable difference in amount.
[h] Jar X was covered with many fine droplets of vaseline.
[DK]

[ ] **25** Blood flowing through the pulmonary veins is distinguished from blood flowing through the jugular vein in the neck region in that the blood in the pulmonary veins –

[a] carries a fresh supply of oxygen
[b] carries antigens for blood type
[c] carries disease-resisting substances known as antibodies
[d] contains nutrient substances, such as sugar, fats, and amino acids
[DK]

[ ] **26** All of the following secrete hormones *except* the –

[e] pituitary gland
[f] islets of the pancreas
[g] adrenal glands
[h] salivary glands
[DK]

[ ] **27** The scientific name of the leopard frog is *Rana pipiens*, and that of the bullfrog is *Rana catesbiana*. These scientific names designate the frogs' –

[a] genus and species
[b] family and species
[c] class and genus
[d] phylum and order
[DK]

[ ] **28** Bearing in mind the conditions necessary for photosynthesis to occur, it should be possible to produce a marked increase in plant growth in a closed greenhouse room by –

[e] drying the air in the room with a calcium chloride apparatus
[f] uncapping a bottle containing a chlorophyll solution and allowing its vapors to pass into the air in the room
[g] slowly releasing a continuous supply of carbon dioxide into the room from a carbon dioxide tank
[h] slowly releasing a continuous supply of pure oxygen into the room from an oxygen tank
[DK]

[ ] **29** Scientists are in the process of cracking the most remarkable code on earth, namely, the code that determines the hereditary nature of every living organism. The specific carrier of this code is –

[a] Bowman's capsule
[b] deoxyribonucleic acid
[c] follicle stimulating hormone
[d] Huntington's chorea
[DK]

GO ON TO THE NEXT PAGE ►

NELSON BIOLOGY TEST—FORM E

For questions 30 through 36, read carefully the following discussion of the inheritance of blood type in man.

In man there are three genes for ABO blood type. They have the following characteristics:

Gene A is dominant to gene O.
Gene B is dominant to gene O.
Genes A and B are *not* dominant to each other.

Every individual inherits two, and only two, of these genes – one from his father and one from his mother. The gene combination that any person has is known as his genotype. The following genotypes are possible:

AA or AO–individual has type A blood
BB or BO–individual has type B blood
AB –individual has type AB blood
OO –individual has type O blood

Another gene, R, is responsible for the Rh factor in the blood. Gene R is dominant to its recessive allele, gene r. With respect to these genes the following genotypes are possible:

RR or Rr–individual has Rh positive blood
rr –individual has Rh negative blood

An individual who has two genes of a pair that are alike, such as RR or rr, is said to be homozygous for this trait. One who has unlike genes, such as Rr, is said to be heterozygous for the trait.

Consider the following description of blood type as found in a man and a woman. Then, on the basis of all information given, select the best answer for each of the questions 30 through 36.

A man is homozygous for blood type B and heterozygous for the Rh factor. His mother belongs to blood group AB and is Rh negative.
This man marries a woman who belongs to blood group A and is Rh positive.
Her father is Rh negative, indicating that the woman carries one recessive gene for Rh.
Her father also belongs to blood group O.
Her mother belongs to blood group A and is Rh positive.

[ ] **30** The genotype of the woman's mother is –
[e] AARr
[f] AaRR
[g] AaRr
[h] impossible to determine
[DK]

[ ] **31** The genotype of the woman's father is –
[a] OOrr
[b] OORR
[c] AOrr
[d] impossible to determine
[DK]

[ ] **32** With respect to ABO and Rh blood types, the woman could produce which of the following kinds of egg cells?
[e] AR and Ar
[f] AR, Ar and OR
[g] AR, Ar, OR and Or
[h] impossible to determine
[DK]

[ ] **33** The man's genotype is –
[a] BBRr
[b] BORR
[c] BORr
[d] impossible to determine
[DK]

[ ] **34** The woman's genotype is –
[e] AARr
[f] AORr
[g] AOrr
[h] impossible to determine
[DK]

[ ] **35** With respect to ABO and Rh blood types, the man could produce which of the following kinds of sperm cells?
[a] BR and Br
[b] BR, Br and OR
[c] BR, Br, OR, and Or
[d] impossible to determine
[DK]

[ ] **36** The only blood groups to which their children could belong would be –
[e] AB and O
[f] AB and A
[g] AB and B
[h] A and O
[DK]

[ ] **37** The deer population could be most effectively increased by –
[a] reducing the number of forest fires, by reforestation and by providing cover for the deer
[b] setting up feeding stations and supplying food for the deer in winter
[c] enacting laws to protect all carnivorous animals
[d] cutting down forests and providing more pasture for grazing
[DK]

GO ON TO THE NEXT PAGE ▶

NELSON BIOLOGY TEST—FORM E

[ ] **38** Which one of the following has a bony internal skeleton?

[e] crayfish
[f] grasshopper
[g] rattlesnake
[h] starfish
[DK]

[ ] **39** Which of the conclusions below might logically follow from the statement:

"The evidence seems to show beyond question that our present species of plants have descended . . . from simpler and fewer species which formerly existed – back, to a single kind which throve in remotest antiquity." – Ganong

[a] The number of plant species is decreasing.
[b] Generally speaking, plants are becoming simpler.
[c] Ancient plants were more successful than modern plants.
[d] The number of plant species is increasing.
[DK]

[ ] **40** The most significant consequence of meiosis is the –

[e] doubling of the number of chromosomes in each cell
[f] maintaining of the diploid chromosome number in each resulting cell
[g] production of sperm or egg cells that are haploid
[h] formation of the spindle within the dividing cell
[DK]

[ ] **41** When a sip of water goes "down the wrong way," there has been improper functioning of the –

[a] larynx
[b] trachea
[c] pharynx
[d] epiglottis
[DK]

[ ] **42** When a virus invades a cell, it may interfere with the host cell's metabolism by causing the cell to manufacture virus-type –

[e] proteins and nucleic acids
[f] fat molecules
[g] glucose molecules
[h] carbon dioxide and carbonic acid
[DK]

[ ] **43** Certain migrating birds seem to arrive in a given locality along the route at the same time each autumn. Their arrival time is fairly constant from one year to the next. This suggests that some environmental factor which is rather constant in its annual recurrence may serve as the stimulus to start this particular species of birds migrating. Which one of the following *possible* stimuli would be fairly constant from year to year?

[a] date of the first killing frost
[b] date when the hours of darkness first exceed the hours of daylight
[c] date when the food supply runs out
[d] date when the vegetation changes to autumn coloration
[DK]

[ ] **44** Consider the following two equations:

$$CO_2 + H_2O^* + \text{energy} \rightarrow \text{glucose} + O_2^*$$
$$CO_2^* + H_2O + \text{energy} \rightarrow \text{glucose} + O_2$$

(O_2 is ordinary oxygen, O^* is heavy oxygen, CO_2 is carbon dioxide and H_2O is water.)

These two equations provide evidence that –

[e] oxygen in the atmosphere very likely comes from the carbon dioxide molecules used by green plants in photosynthesis
[f] oxygen in glucose manufactured in photosynthesis comes from the water molecules
[g] many substances entering the photosynthesis reaction cannot be accounted for in the end products
[h] oxygen released to the atmosphere in photosynthesis probably comes from the water molecules entering into the photosynthesis equation
[DK]

[ ] **45** It is sometimes desirable when seeding a new lawn in poor soil to mix a small amount of white clover seed with the grass seed because the clover –

[a] tends to crowd out weeds
[b] produces carbon dioxide
[c] has root structures which harbor nitrogen-fixing bacteria
[d] protects the young grass plants from injury until the turf is well established
[DK]

GO ON TO THE NEXT PAGE ▶

NELSON BIOLOGY TEST—FORM E

For questions 46 through 49, read carefully the following account of two experiments designed to demonstrate changes in osmotic pressure due to movements of water molecules.

Water molecules will move through a cell from a region of lesser concentration to a region of greater concentration of dissolved substances. If the concentration is the same both inside and outside the cell, a state of osmotic equilibrium exists and water molecules will enter and leave the cell at the same rate. Consider the following experiments:

EXPERIMENT I. Several long strips of raw potato (shaped like "French fries") were placed in a beaker containing 200 cc. of cold distilled water. These were allowed to stand for a half hour, after which the potato strips were examined.

EXPERIMENT II. Several long strips of raw potato were placed in a beaker containing 200 cc. of saturated salt solution. These were also allowed to stand for a half hour, after which the potato strips were examined.

Classify each of the questions 46 through 49 according to the following KEY:

KEY
- [e] Occurred in or was related to Experiment I.
- [f] Occurred in or was related to Experiment II.
- [g] Occurred in or was related to *both* Experiment I and Experiment II.
- [h] Occurred in or was related to *neither* Experiment I nor Experiment II, though relevant to them.
- [DK]

[ ] **46** Water molecules passed through the membranes surrounding the potato cells.

[ ] **47** More water molecules passed out of the potato cells than entered these cells.

[ ] **48** The concentration of fluids remained unchanged inside the cells.

[ ] **49** More water molecules entered the potato cells than passed out of these cells.

[ ] **50** Coal beds found in Antarctica tend to indicate that at some time in the past Antarctica –
- [e] had numerous actively erupting volcanoes
- [f] was completely submerged under water
- [g] had a dense cover of semi-tropical vegetation
- [h] has been the scene of radioactive transformation
- [DK]

[ ] **51** The pancreas functions as a part of –
- [a] both the digestive system and the endocrine system
- [b] the digestive system only
- [c] the endocrine system only
- [d] neither the digestive nor the endocrine system
- [DK]

[ ] **52** A person is able to maintain his balance when he sits, stands, or walks, primarily because of the functioning of the –
- [e] medulla oblongata
- [f] spinal cord
- [g] solar plexus
- [h] semicircular canals
- [DK]

[ ] **53** Which cell structure becomes one of the poles of the spindle during mitosis?
- [a] mitochondrion
- [b] centrosome
- [c] golgi body
- [d] ribosome
- [DK]

[ ] **54** What theory is being defended by the author of the following passage?

"So we may doubt whether, in cheese and timber, worms are generated or if beetles and wasps in cow dung, or if butterflies, shellfish, eels, and such life be procreated of putrefied matter. To question this is to question reason, sense, and experience. If he doubts this, let him go to Egypt, and there he will find the fields swarming with mice begot of the mud of the Nile, to the great calamity of the inhabitants." – Ross

- [e] sexual reproduction
- [f] biogenesis
- [g] spontaneous generation
- [h] regeneration
- [DK]

GO ON TO THE NEXT PAGE ►

NELSON BIOLOGY TEST—FORM E

[ ] **55** Glucose is oxidized at a much lower temperature inside living cells than over a flame mainly because of the presence in living cells of –

[a] oxygen
[b] water
[c] carbon dioxide
[d] enzymes
[DK]

[ ] **56** Which of the following is characteristic of every individual living organism on the earth?

[e] It has a nucleus in each cell.
[f] It uses oxygen from the atmosphere.
[g] It uses energy in carrying on its life processes.
[h] It can adapt to changes in environment.
[DK]

[ ] **57** How should the *italicized* portion of the following statement be classified? "If chromosomes convey to the daughter cells all the capacities of the mother cell, *then the chromosomes must be the agents of heredity.*"

[a] deduction
[b] generalization
[c] observation
[d] analogy
[DK]

[ ] **58** The RNA molecule has the same bases as the DNA molecule except that uracil replaces thiamine and the RNA molecule has a single strand rather than a double helix. An RNA molecule would, therefore, be represented by which one of the following?

[e] C-G-A-T
[f] C-G-A-U
[g] C-U-A-T
[h] C-G-U-T
[DK]

For questions 59 through 62, select from the KEY below the name of the digestive organ whose structure or function is described in each question.

KEY
[a] pancreas
[b] liver
[c] small intestine
[d] large intestine
[DK]

[ ] **59** Bile is manufactured in this organ.

[ ] **60** One of the functions of this organ is water conservation. As indigestible food residues pass slowly through this organ, water is absorbed and returned to the body tissues.

[ ] **61** The interior absorbing surface of the walls of this organ is enormously increased by many tiny villi present in the inside wall surface.

[ ] **62** This organ secretes a hormone that regulates the use of carbohydrates by the body. A deficiency of this hormone may be indicated by the presence of sugar in the urine.

Questions 63 through 65 involve a comparison of DNA and RNA molecules. Classify each question according to the following KEY:

KEY
[e] Characteristic of DNA molecules only.
[f] Characteristic of RNA molecules only.
[g] Characteristic of *both* DNA and RNA.
[h] Characteristic of *neither* DNA nor RNA.
[DK]

[ ] **63** Messenger service appears to be one of the functions.

[ ] **64** The base guanine is present.

[ ] **65** There is a double helix of sugar-phosphate groups.

STOP! GO BACK AND CHECK YOUR WORK

7 8 9 10 11 12 A B C D E

Appendix E: Student scores on Scientific Attitude Inventory

SCIENTIFIC ATTITUDE INVENTORY SCORES

CONTROL (GROUP A)
Lecture-Only

Student Number	Pre-test Scores	Post-test scores
1	127	110
2	111	119
3	115	113
4	134	119
5	137	117
6	97	89
7	136	133
8	127	112
9	127	114
10	125	103
11	99	126
12	120	143
13	119	119
14	99	112
15	123	118
16	116	117
17	122	143
18	137	138
19	141	147
20	113	113
21	111	117
22	106	120
23	103	117
24	129	130
25	117	119
26	107	129
27	127	142
28	140	160
29	105	121
30	124	127

Control (Group A)--Continued
Lecture-Only

Student Number	Pre-test Scores	Post-test Scores
31	116	123
32	116	130
33	117	122
34	115	111
35	111	109
36	131	128
37	109	112
38	133	147
39	116	118
40	108	117
41	94	117
42	121	109
43	99	101
44		
45		
46		
47		
48		
49		
50		

Lecture-Laboratory (Group B)

Student Number	Pre-test Scores	Post-test Scores
1	119	148
2	133	138
3	122	112
4	123	132
5	106	120
6	114	127
7	135	126
8	139	133
9	119	130
10	140	147
11	109	111
12	119	131
13	133	136
14	125	139
15	146	159
16	129	149
17	116	122
18	114	116
19	117	131
20	131	132
21	143	145
22	114	132
23	117	131
24	125	138
25	130	140
26	124	133
27	119	127
28	112	144
29	113	135
30	114	126

Lecture-Laboratory (Group B)--Continued

Student Number	Pre-test Scores	Post-test Scores
31	110	120
32	112	126
33	123	114
34	115	120
35	110	107
36	121	136
37	122	132
38	123	132
39	134	123
40	124	129
41	120	138
42	113	120
43	130	131
44		
45		
46		
47		
48		
49		
50		

Lecture-Recitation (Group C)

Student Number	Pre-test Scores	Post-test Scores
1	133	140
2	126	136
3	129	134
4	145	151
5	123	131
6	119	140
7	126	127
8	126	145
9	99	102
10	141	137
11	118	123
12	103	134
13	117	131
14	117	121
15	107	113
16	142	129
17	113	135
18	106	122
19	112	141
20	130	144
21	116	133
22	125	136
23	114	113
24	115	108
25	132	133
26	130	140
27	124	133
28	123	131
29	130	127
30	115	114

Lecture-Recitation (Group C)--Continued

Student Number	Pre-test Scores	Post-test Scores
31	105	137
32	132	122
33	136	135
34	114	141
35	128	104
36	90	122
37	153	149
38	139	152
39	140	140
40	135	148
41	154	153
42	124	131
43	130	132

Appendix F: Student scores on Investigator-Constructed Test

Raw Score Data
Control (Group A)
Lecture-Only

Student Number	Investigator Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
1	39	43	24	33
2	29	41	20	19
3	33	46	19	28
4	72	73	53	62
5	50	68	36	46
6	26	25	12	6
7	42	68	26	45
8	33	49	30	33
9	50	63	35	44
10	25	45	18	19
11	32	33	12	39
12	50	75	40	56
13	16	45	16	16
14	30	35	12	23
15	49	77	36	56
16	53	64	30	45
17	47	66	38	54
18	53	66	37	56
19	47	54	26	36
20	27	45	22	30
21	34	62	29	44
22	53	58	47	54
23	24	27	4	12
24	49	65	31	42
25	51	65	42	42
26	41	71	25	51
27	58	73	44	58
28	46	69	46	58
29	40	52	32	47
30	36	43	28	32

Control (Group A)--Continued

Control (Group A)

Student Number	Instructor Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
31	44	73	28	49
32	29	50	21	26
33	42	65	20	57
34	27	55	20	37
35	46	53	28	43
36	25	57	35	39
37	51	66	49	54
38	32	62	34	43
39	48	65	48	53
40	44	66	29	41
41	31	50	22	36
42	59	48	38	43
43	40	46	30	37

Lecture-Laboratory (Group B)

Student Number	Instructor Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
1	40	70	35	55
2	31	59	26	47
3	50	56	31	34
4	40	64	26	41
5	45	75	36	53
6	33	59	36	43
7	41	62	19	51
8	43	64	30	34
9	39	58	32	37
10	48	63	33	48
11	39	53	28	36
12	36	66	22	38
13	43	56	35	51
14	45	70	29	42
15	30	66	13	45
16	54	82	52	61
17	40	65	40	52
18	53	77	50	63
19	47	75	33	54
20	41	72	42	59
21	38	78	23	57
22	37	70	26	47
23	48	59	22	40
24	38	61	37	50
25	35	65	25	40
26	35	54	16	35
27	35	60	26	58
28	37	77	34	43
29	31	45	20	36
30	55	75	51	56

Lecture-Laboratory (Group B) Continued

Student Number	Instructor Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
31	41	49	24	36
32	31	46	29	28
33	38	60	24	43
34	53	74	30	54
35	27	67	14	51
36	32	65	24	38
37	36	60	27	46
38	42	68	36	48
39	47	58	36	51
40	50	67	45	53
41	45	63	45	54
42	37	51	21	39
43	41	60	33	37

Lecture-Recitation (Group C)

Student Number	Instructor Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
1	50	78	54	62
2	38	56	32	51
3	41	71	37	60
4	59	67	52	62
5	37	39	23	33
6	36	42	22	29
7	22	38	20	24
8	44	55	17	38
9	34	61	14	35
10	44	61	37	43
11	26	54	26	45
12	29	56	30	37
13	30	70	19	33
14	27	59	18	46
15	42	52	27	43
16	40	47	21	45
17	36	54	19	48
18	20	44	10	45
19	45	71	28	59
20	56	69	35	49
21	56	61	35	41
22	42	71	25	51
23	45	57	26	46
24	29	42	13	30
25	27	47	32	47
26	46	66	34	52
27	29	71	24	46
28	43	69	34	53
29	41	47	28	33
30	32	29	19	24

Lecture-Recitation (Group C) Continued

Student Number	Instructor Test		Nelson Biology Test	
	Pre-test	Post-test	Pre-test	Post-test
31	43	58	28	47
32	34	65	31	47
33	42	51	34	47
34	34	46	17	27
35	31	64	25	42
36	42	67	34	45
37	54	66	43	54
38	45	50	23	45
39	58	65	47	49
40	41	61	38	40
41	40	68	31	53
42	44	72	35	55
43	36	75	29	50

Appendix G: Student scores on SCAT Test

SCAT TEST RAW SCORES

Control (Group A)

Lecture-Only

Student Number	SCAT Scores (Verbal + Quantitative)			%ile
1	44	31	13	16
2	31	18	13	6
3	44	32	12	16
4	99	53	46	97
5	67	40	27	48
6	34	16	18	8
7	68	43	25	55
8	43	24	19	14
9	62	32	30	42
10	24	15	9	2
11	66	37	29	48
12	89	47	42	89
13	60	36	24	37
14	54	25	29	28
15	80	47	33	80
16	77	43	34	74
17	74	36	38	68
18	68	40	28	55
19	68	38	30	55
20	41	26	15	11
21	74	42	32	68
22	59	36	23	37
23	34	17	17	8
24	65	42	23	48
25	67	34	33	48
26	83	39	44	84
27	97	55	42	96
28	79	41	38	74
29	72	31	41	62
30	43	22	21	14

Control (Group A)--Continued
Lecture-Only

Student Number	SCAT Scores (Verbal + Quantitative)			%ile
31	89	53	36	89
32	39	24	15	11
33	77	48	39	74
34	48	27	21	20
35	64	40	24	42
36	54	34	20	28
37	85	45	40	84
38	76	34	42	68
39	88	52	36	89
40	60	30	30	37
41	52	31	21	24
42	93	52	43	93
43	74	43	31	68

Lecture-Laboratory (Group B)

Student Number	SCAT Scores (Verbal + Quantitative)			%ile
1	81	38	43	80
2	62	31	31	42
3	65	34	31	48
4	47	24	23	20
5	65	39	26	48
6	59	30	29	37
7	62	38	24	42
8	60	25	35	37
9	42	30	12	14
10	72	44	28	62
11	47	31	16	20
12	67	30	37	48
13	66	35	31	48
14	88	51	37	88
15	84	50	34	84
16	101	56	45	98
17	91	47	44	92
18	105	55	50	99
19	73	44	29	62
20	99	56	43	97
21	61	30	31	42
22	70	35	35	55
23	52	28	24	28
24	62	31	31	42
25	56	35	21	32
26	61	29	32	42
27	71	33	30	62
28	54	32	22	28
29	59	28	31	37
30	91	41	50	92

Lecture-Laboratory (Group B)--Continued

Student Number	SCAT Scores (Verbal + Quantitative)			%ile
31	56	31	25	32
32	41	27	14	11
33	77	49	28	74
34	79	48	31	74
35	67	29	38	48
36	73	43	30	62
37	72	35	37	62
38	65	27	38	48
39	77	40	37	74
40	77	40	37	74
41	70	44	26	55
42	61	31	30	48
43	69	39	30	55

Lecture-Recitation (Group C)

Student Number	SCAT Scores	(Verbal	+ Quantitative)	%ile
1	90	48	42	89
2	73	36	37	62
3	95	53	42	94
4	84	44	40	84
5	69	42	27	55
6	52	31	21	24
7	44	25	19	16
8	70	49	21	55
9	58	21	37	37
10	63	34	29	42
11	62	31	31	42
12	38	18	20	9
13	43	31	12	14
14	74	34	40	68
15	74	39	35	68
16	59	32	27	37
17	55	28	27	28
18	47	24	23	20
19	80	50	30	80
20	76	35	41	68
21	48	28	20	20
22	81	48	33	80
23	71	42	29	62
24	40	27	13	11
25	68	31	37	55
26	84	45	39	84
27	79	42	37	74
28	60	37	23	37
29	68	34	34	55
30	37	23	14	9

Lecture-Recitation (Group C)--Continued

Student Number	SCAT Scores	(Verbal +	Quantitative)	%ile
31	69	37	32	55
32	65	43	22	48
33	67	39	28	48
34	57	32	25	32
35	69	31	38	55
36	85	53	32	84
37	87	48	39	87
38	65	32	33	48
39	96	52	44	94
40	58	40	18	37
41	85	45	40	84
42	94	51	43	93
43	83	50	33	84

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