AN EXPERIMENT ON METHODS OF TEACHING ZOOLOGY.¹

By J. P. GILBERT,

*Supervisor of Practice Teaching, School of Education,
University of Illinois School, Urbana, Ill.*

For a long time there has been much discussion as to the relative merits of pure science and applied science in education. Probably all would agree that applied science would best influence the later economic adjustment of the individual. Yet there are many who contend that applied science would result in a distinct loss to education, a loss which would show a marked deficiency in culture. This view is strongly maintained in an article in a recent number of *Science*. The contention is stoutly denied, however, by those who favor a maximum amount of applied science in the curriculum. In so far as I have been able to learn, the arguments pro and con have been purely mental exercises worked out in the study without any data or experimentation on which to base such philosophy.

In these arguments there must always enter the inseparable question of the relative merits of the pure science and the applied science methods of approach in the teaching of secondary school science. The present study was undertaken to determine the relative merits of these two methods of approach to the study of secondary school zoölogy. The effort was made to contribute some definite and tangible data as to the effect of these two methods of approach, not upon the economic adjustment of the pupil, but rather upon the disciplinary or cultural outcome of his science work.

A summary of results at the very outset may be helpful in enabling you to hold in mind the cardinal points of the discussion. This experiment was reported in the June number of the *Journal of Educational Psychology* and I shall quote very freely from that report.

SUMMARY OF RESULTS.

I. The results are only suggestive, in view of the small number of individuals tested. Even allowing for the probable error, however, the applied science method of approach to the study of secondary school zoölogy appears to have a slight advantage over the pure science approach, when tested by examination

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grades (the examination being of the pure science type). When tested by average semester grades, the applied science approach shows a somewhat greater advantage. When tested by the per cent of pupils averaging more than eighty-five per cent in the semester's work, the applied science approach has a slight but appreciable advantage.

2. When tested by the ability of the pupils to set up experiments and interpret phenomena (a cultural and disciplinary standard), the applied science approach has a decided advantage.

3. When tested by the interest aroused as revealed in the voluntary "outside" reading of the pupils, the results are uncertain.

4. The method of investigating class room problems by comparing the progress of parallel groups of pupils promises to yield valuable results, but it should be carefully studied, and its technique refined through repeated tests.

METHODS AND RESULTS.

The method of conducting the experiment, by the use of parallel groups (employed perhaps most notably by Winch in his memory investigations), is comparatively new, and should prove of service in questions of method of teaching such as the one under consideration.

The experiment was performed in the academy of the University of Illinois during the first semester, 1909-10. Two sections of the class of beginners in zoölogy were used. These sections were approximately equal in size. They used the same laboratory and apparatus, the same text-books and laboratory guides, and were both taught by the speaker. The same subject matter was covered, and the same examination questions and tests were given to both groups. No selection of students for either section was attempted. Furthermore, the students were not informed of the experiment either upon registration or during the semester. They could not, therefore, choose one section or the other because of individual preference.

The data summarized below seem to indicate that the two sections were fairly equal with respect to distribution of sex, age, former environment, and professional bent. In computing the averages one student (forty-two years old) was not considered.

NUMBER IN SECTIONS:

A, 17.

B, 15.

DISTRIBUTION AS TO SEX:

A—boys, 15; girls, 2.

B—boys, 13; girls, 2.

AGE:

Average age—A, 18.7 (average variation, 1.0).

B, 19.1 (average variation, 1.7).

FATHERS' OCCUPATIONS:

A—agriculture, 6; medicine, 1; other occupations, 10.

B—agriculture, 6; medicine, 0; other occupations, 9.

STUDENTS' FORMER OCCUPATIONS:

A—4 have worked on the farm; 5 in other occupations.

B—4 have worked on the farm; 5 in other occupations.

STUDENTS' INTENDED OCCUPATIONS:

A—agriculture, 1; medicine, 3; other occupations, 13.

B—agriculture, 0; medicine, 2; other occupations, 11;
undecided, 2.

Throughout this report the so-called cultural and disciplinary group is known as Section A. The enrollment was 17—15 boys and 2 girls. It recited from 8 to 10 a. m. The so-called economic group is called Section B. The enrollment was 15—13 boys and 2 girls. It recited from 11 a. m. to 12 m., and worked in the laboratory from 1 to 3 p. m. It should be noted that Section B recited at a period of the day not so favorable for the best work as that used by Section A. (Cf Burgerstein and Netolitzky: *Handbuch der Schulhygiene*, Jena, 1902, p. 572.)

A brief statement of some of the differences in approach and treatment of some topics used will best explain the method of conducting the experiment.

Illustrative Details of Methods of Instruction.—In studying the mouth parts of insects, Section A inquired as to the significance of these structures and adaptations in enabling the possessor to maintain its existence and be successful as a living creature. Section B made the same inquiry, but dwelt upon this significance for a shorter period and asked at some length the economic importance of these structures and their adaptations to the destruction of crops and property and to the spread of disease.

Section A visited a market garden and found aphids upon the vegetables, particularly upon cabbage plants. They studied such points as the great numbers, wide distribution, rapid multiplication, suctorial mouth parts, parthenogenesis, etc., of these creatures as factors which make them successful as a species. Sec-

tion B found the same aphids and discussed the same points more briefly. They then considered the extent of the injury done in the garden and how parthenogenesis, rapid reproduction, and wide distribution of aphids contribute to the destruction of vegetables and other crops. Section A discussed the sucking mouth parts of aphids, squash bugs, and other Hemiptera as adaptations which enable these insects to employ a particular method of obtaining food from beneath the epidermis of the food-plant or animal. Section B noted the same points, but gave considerable time to a discussion of the fact that this particular type of mouth parts is responsible for the very large number of exceptionally injurious species to be found in this order, such species, for example, as plant lice, scale insects, squash bugs, cicadas, chinch bugs, bed bugs, etc. In this connection it was pointed out that the arsenical stomach poisons used effectively against the Colorado potato beetle and similar insects with biting mouth parts are of little service against this group with beaks which may pierce the epidermis of the plant and suck the juices from beneath the coat of poison. Therefore, if the Hemiptera are to be destroyed artificially, it must be in some other manner, as by contact poisons in the form of washes and sprays, or by the fumes of poisonous gases. It is manifestly far more difficult to place poison in contact with each individual insect than to spread it upon vegetation where biting jaws would devour it. In the study of the mouth parts, then, the economic section saw a partial explanation of the large per cent of Hemiptera which are both injurious and difficult to control. This discussion was followed by a brief study of methods controlling injurious Hemiptera.

Section A observed the lady-bird devouring aphids to satisfy its appetite and maintain its existence. Attention was called to the fact that the little insect gives off a fluid which is distasteful to birds, toads, etc., which might otherwise feed upon it. The class observed that the lady-bird is conspicuously marked, and, remembering that it is unpalatable, concluded that this might well be considered a warning coloration. Section B noted the little beetle devouring aphids, and, knowing the harm done by plant lice, at once concluded that the lady-bird is exceptionally beneficial to man. They discussed, also, the bad tasting fluid which repels enemies, and noted the conspicuous color, but looked upon these provisions as fortunate means of protecting the very valuable little creature from destruction by predaceous animals.

Section A found tomato worms and noted their food, their color

corresponding to the foliage, their means of holding on to the stems, the parasitic Hymenoptera emerging from the caterpillars, and the weakened condition or death of the tomato worm as a result. Section B noted all these points, but estimated the damage done to the patch of tomatoes, figured the per cent of parasitized forms, and concluded that a very large per cent of these insects are killed by the parasite, and that the ultimate damage done by them is perhaps correspondingly diminished.

The tongues of the frog and toad were discussed by Section A as organs especially adapted in point of attachment and in structure for obtaining insects used as food. Section B looked upon the organ as one not only enabling the toad to get its own food, but also as one which fortunately enables the toad to perform great service to man by destroying injurious insects on farms. Section A observed the extensible horny-tipped tongue of the woodpecker as a structure used to spear and extract the grubs from the trees after the chisel-like beak has made the opening in the bark. Section B saw in this structure a means not only of obtaining food for the bird, but also a means of saving our forest and fruit trees from grub and borer injury to the amount of many million dollars annually.

Section A discussed bird migration, noting its causes and its effects upon the bird population of the region and upon the species migrating. Common birds were classified as permanent residents, summer residents, winter residents, transients and accidental visitors. Section B discussed the effect of migration upon the food of the bird, and on the insects and weed seeds destroyed in a given region. If a bird's food habits are good, it is most beneficial in the locality if it resides there permanently. It perhaps is of next greatest value if it is a summer resident and nests in the locality. This is particularly true since young birds are so frequently fed upon injurious caterpillars and grubs. Each group of migrants was discussed with reference to the value of its individuals in an economic way. To Section B this classification meant in part, that a bird was of greater or less value on the farm and in the forest accordingly as it fell into one or the other of these groups.

In like manner Section A learned the distribution and number of birds in pastures, plowed fields, forest, etc., where they obtain the particular foods they most desire. Section B learned this distribution and asked what significance it might have in holding in check the particular destructive insects found there.

The preceding examples, while not given in great detail, will indicate some of the differences in points emphasized in the two sections.

Methods of Testing.—Perhaps few experiments are more complicated than the one here undertaken. Numerous factors enter into the results, and some of these factors are not easily controlled. For example, by reason of previous training or occupation some students in Section A may have developed strong economic tendencies, which might easily serve as a source of interest in the study of biological forms. This would tend to minimize any real advantage gained by the economic section. Furthermore, much difficulty was experienced in the development of a technique. In fact, the solving of problems of method rather overshadowed the obtaining of definite data, and must continue to do so, in a diminishing degree, until the method of attack is perfected.

Results were compared mathematically upon:

1. The amount of zoölogical knowledge assimilated.
2. The power to set up simple experiments and to interpret phenomena.
3. The interest of the sections.

The Examination Test.—The amount of knowledge assimilated was tested in the usual way, by written examinations, the same questions being given to both sections. Every effort was made to avoid the economic element in the questions asked so that Section A would be under no disadvantage. The questions were made to cover the field of study pretty generally and to search the ground rather thoroughly. The final examination questions will serve as a type and were as follows:

1. Define the following zoölogical terms, and give an example of each: mimicry, homology, analogy, instinct, intelligence, parthenogenesis, exoskeleton, endoskeleton, vertebrata, imago.
2. Discuss the relation of insects to disease.
3. Discuss the relation of insects to flowers. (Omit discussion of the milkweed studied in the laboratory.)
4. Give the life histories of the mosquito, the housefly, and the frog.
5. Define evolution, natural selection, hybrid, dominant. State Mendel's law of heredity as it applies to white and gray rabbits.
6. Compare the respiratory and circulatory systems of the locust, the crayfish, the frog, the bird, and the rabbit.

7. Give characteristics and examples of: Orthoptera, Odonata, Hemiptera, Coleoptera, Diptera, Hymenoptera.

8. To what class and order does each of the following animals belong: Ostrich, owl, bob-white, cat, horse, crayfish, green-frog, butterfly, black-snake, man?

9. Define carapace, cephalothorax, somite, exopodite, palpus, metathorax, ocelli, gastric mill, cheliped, cerebrum, amoeba, arthropoda.

10. What animals can you find abundant in the fall in cabbage fields and gardens, in weed and stubble fields, in stagnant, filthy water, such as that near the Smith Packing House, in the dredge ditch, in a dusty road? (Recall your field trips.)

Results of the Examination Test.—The examination papers were numbered and the grades recorded before the names of students holding these numbers were known to the instructor. This was, of course, done to eliminate the personal equation in judging results. Section A made an average grade of 72.5 per cent in the final examination, while Section B made an average grade of 73.2 per cent.

Results of Comparing Semester Grades.—The average semester grade for all subjects other than zoölogy of the students in Section A is 80.35 per cent. In zoölogy the average of the same student for the semester is 81.53 per cent. The average semester grade of the students in Section B in all subjects other than zoölogy is 78.47 per cent. In zoölogy their average for the semester is 82.73 per cent. Section A, then, has an average in zoölogy which is 1.18 per cent higher than their average in other subjects. Section B has an average in zoölogy which is 4.26 per cent higher than the average in other subjects. In all subjects other than zoölogy Section A has an average which is 1.88 per cent higher than that of Section B. In the final examination, however, Section B has an average grade which is 0.7 per cent higher than that of Section A. After calculating the probable error in all the data obtained, a very slight advantage appears in favor of the economic approach. While this advantage is too small to warrant any final conclusions upon a single trial of the experiment, it does warrant the conclusion that the experiment is worth repeating with the hope of obtaining more conclusive data as the technique is perfected.

Results of Comparison of Pupils Averaging Over 85 Per Cent.—Viewed from another standpoint, the grades are even more in-

interesting than is indicated above. The per cent of students making above 85 was 29.4 in Section A and 46.6 in Section B. The per cent making from 75 to 85 was 41.1 in Section A and 33.3 in Section B. The per cent making from 70 to 75 was 23.5 in Section A and 13.3 in Section B. This seems to point to a rather clear advantage for Section B. However, if this advantage exists in a rather marked way as indicated in these figures, it may be asked why the average of Section B is so little above that of Section A. The fact of the matter is that in Section B there was a case of premature love-sickness, a thing which high school teachers will admit is difficult to control so long as the parties are thrown together in the class. Perhaps no method of presenting subject-matter will greatly influence such cases. These two students materially lowered the average of Section B.

Frequency curves (not published in this preliminary report) were plotted both for the examination grades, and for the pupils averaging over 85. They show a uniform advancement of the "stations" of the various groups of Section B, as compared with analogous groups in Section A, while the frequency curves for grades in other subjects show the inverse relation.

The Test for Ability in Experimentation and Interpretation: Its Results.—The following is an example of the method used to test the ability of students to set up experiments and interpret phenomena. The supply table was provided with all necessary containers and apparatus for transfer of materials; with thermometers, food materials, etc., for the experiment. Mosquito larvae of uniform age and size were placed on the table, and the classes were directed to determine by experiment the effect of abundance and scarcity of food supply upon the rapidity of growth and development of mosquito larvae. The individual student was then required to write out a detailed account of the steps to be taken and present this for approval. This precaution prevented the possibility of students getting suggestions by seeing other students at work on the same problem. Defects such as failure to specify that the containers in the experiment must be placed under the same temperature and light conditions were checked against the student, and he was required to make a second report. Of students in Section A, 35 per cent reported correctly on the first trial, and 47 per cent more were correct on the second report. Of students in Section B, 60 per cent reported correctly on the first trial, and 33 per cent more were correct on the second trial.

This gives an advantage on first reports in favor of the economic section.

The Test for Interest and Its Results.—As to interest, while the speaker is confident that much the greatest advantage in favor of the economic section was found here, he does not care to represent this difference in mathematical terms until he has better control of some of the factors involved. Readings from Burroughs, the Peckhams, Darwin, Huxley, Wallace, De Vries, Jordan, Kellogg, etc., were assigned to Section A. Reading from numerous bulletins from the Department of Agriculture at Washington and from the state experimental stations were assigned to Section B. Records of voluntary readings by the two sections were somewhat vitiated by the fact that books wanted were frequently in use by other departments of the University. Figures are, therefore, not given on this point. Interest, however, both in the regular class work and discussions and in the outside work seemed to be greater in the economic section and it was here that the results seemed to be most favorable to the economic approach. More definite and reliable data can be obtained on this point in future experiments.

CONCLUSIONS.

One chief concern of the speaker in performing this experiment was to satisfy his own mind as to the feasibility of getting data of real value by this method of experimentation. The only definite conclusions which the experiment justifies are that the method, with such modifications as experience will bring, can be applied successfully, and that the problem of the relative merits of methods of approach to zoölogy is worthy of serious consideration and experimentation.

The speaker is also very anxious that other teachers interested in this type of pedagogical problem should try the method here suggested, and that they should contribute first to the development of the needed technique, and finally to the determination of the relative merits of pure science and applied science in education and of the best method of approach to the study of biology.

The experiment was continued during the second semester of last year upon two sections of beginners in botany. Since registration resulted in mixing students from the two zoölogy classes and since, also, the botany classes became the dumping ground for students who had failed in the first half of various one year courses, I do not feel justified in giving very much weight to the

results of this additional test. I should say, however, that the results are even a bit more favorable to the economic approach than was the case in the more reliable data of the first trial of the experiment.

During the present year I am continuing the experiment in zoölogy, giving an entire year to the subject instead of the course for one semester of last year. This will make possible a more careful and more efficient test of results.

You will note that mention has been made only of the effect of this experiment upon the student. Professor S. A. Forbes, state entomologist of Illinois, so forcibly focused my attention upon an additional point, that I must include it in this discussion. This point is the effect which such experimentation has upon the teacher. I quite agree with him that the teacher with such an experimental end in view will bring greater efficiency into the teaching of all his classes. The attention of the experimenter must be focused upon the purpose of the course and the parts of the course, and a clearer definition of the ends to be attained is inevitable. We are told that a most serious defect among teachers is that most of them are unable to tell, with any degree of clearness, what they expect to accomplish with the particular course or the particular subject matter they are presenting. Such an experiment as here undertaken would go a long way toward eradicating this evil and toward enabling the teacher to organize the course toward the attainment of some definite goal to which he might lead his pupils.

Every observer knows full well how the great majority of students proceed to forget nearly all their secondary school science in a remarkably short time. I hope to devise means of testing some of these students to determine which group of students remember the subject better. This will manifestly be difficult and possibly not entirely reliable, but I believe that it can be made to throw some valuable light upon the question at issue.

In former discussions those who advocated applied science have been forced to take the defensive. While the data here obtained do not finally settle the question of the relative merits of the pure science and applied science approaching to secondary school zoölogy, they do shift the burden of proof to those who advocate the cultural approach.

Dr. W. C. Bagley, Director of the School of Education of the University of Illinois, approved the plans of the experimenter, and he gave much encouragement and helpful advice which were of

great value in the effort to solve this difficult problem. Working conditions are not of the best in the academy where this experiment is being made, and some improvements have been withheld because the academy is to be discontinued at the close of the present academic year. The Legislature of the state will be asked to establish a model high school as a part of the School of Education, using the present academy as a basis.

THE PHYSICAL VERSUS THE HUMAN SIDE OF PHYSIOGRAPHY.¹

(ABSTRACT.)

BY GRACE ELLIS,
Grand Rapids, Mich.

The purpose of physiography is first of all to educate the pupil, just the same as any other subject. Physiography is perhaps an uncommonly good subject for a pupil to learn to think straight through a problem, and to talk to the point. While he is doing this he may well learn proper methods of study; how to study, how to work; how to reason from one thing to another; to get his data first, and get all the available data on the subject, and from them to form his conclusions; and not to make conclusions too big for his data. It makes for intellectual honesty to reason straight.

If you can at the same time get students to see the partialness of many conclusions, they reach a point where they do not necessarily want a yes or no; but may work for the truth, for the sake of what may be done with it.

There are no dull moments in a subject which may at any time turn up a fact which affects you even remotely. The results of the cutting of valleys in strata of horizontal rock is a very different thing when the theory of the book is to be applied to your own river, in your own home, and the power it develops and the flour mills it can run. Latitude and day length are vital when it is they which determine whether or no the wheat to supply these mills can be raised in your vicinity.

When the fundamental facts of any section of the subject have been learned, then they should be applied to the place the child knows most about, if such application is possible, and their bearing on human life made evident.

¹Read before the Earth Science Section C. A. S. and M. T., Cleveland, 1910, meeting.