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During the school year 1963-64 a study was undertaken at Columbus High School, Waterloo, in order to discover whether the new science programs are more effective in teaching problem solving and critical thinking than are the traditional courses. Critical thinking, reflective thinking, and problem-solving, terms which some writers use synonymously have been stressed as abilities which should be instilled in our students in order that they might, as adults better meet the growing needs of our democracy.

Sister Janela

Until now, schools and teachers have failed to promote this fundamental requisite of education, namely, critical thinking. Certainly most of the textbook writers have not encouraged this course of thought. Recently, national curriculum studies supported by the National Science Foundation have endeavored to switch the science courses to more student activity. The incorporating problem-solving and the testing of the hypotheses in the laboratory have required students to use thought processes to greater advantage. The teacher has been faced with the problem of changing the attitudes of the self_satisfied beings in front of him from a passive to an active, critical way of thinking. Burnett says:

"Some of our critics have gone so far as to say that the typical science teacher has done more to thwart the development of critical thinking processes than any other teacher of the school. An amazing indictment surely! . . . It is desirable, therefore, that we examine what we have been doing and compare it with newer programs that are supposedly designed to meet the criticism and to better achieve the objectives we hold. [1]"

Since science can aid in developing habits of critical thinking, biology was thought to be a feasible and timely subject for this study. The achievement and development of critical thinking, over a school year period, was compared between groups of sophomores. One group used BSCS Blue Version biology, a new modern approach, and the other group was taught biology via the traditional method.

To clarify the terminology, **BSCS Blue Version biology** is one of the three editions of modern experimental biology that was developed by the Biological Sciences Curriculum Study Group. This version emphasizes the biochemical and physiological aspects of organisms. It was used in this study since critical thinking is thought to be promoted by the BSCS materials. **Traditional biology** is biology, as it has existed for years, with emphasis

[1] R. Will Burnett, "The New and the Old in Science Teaching," **Science Education**, XXV (February, 1951) 45.

on memorization of scientific facts and principles. The teacher expected the student to accumulate a sufficient quantity of scientific information separated, for the most part, from the processes of inquiry. **"Critical thinking,"** according to Carter V. Good in the **Dictionary of Education.** "is thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions as objectively as possible through the consideration of all pertinent factors and the use of valid procedures from logic."

Requests to Educational Testing Agencies revealed that very little had been done the past decade in preparing biological tests, and none that would satisfactorily test the modern method involving problem-solving and critical thinking with the exception of the BSCS Impact Test. There was one instrument available to test the ability to think critically but not specifically for the biological field. After much investigation and discussion the following instruments were selected for this study: (1) Otis Quick Scoring Mental Ability Gamma Test (2) Nelson Biology Test (3) Hilliker's General Information Test in Biology taken from a thesis (4) Watson-Glaser Critical Thinking Appraisal (5) The BSCS Impact Test which had been recommended as a measure for both the students' achievement and their ability to think critically (6) Results of the Iowa Tests of Educational Development and (7) the point hour ratios of the students in this study.

The hypothesis tested was: Critical thinking can be better developed by BSCS Blue Version biology than by traditional biology and the students using BSCS materials can achieve as well as, if not better, than the students of traditional biology.

During the first two weeks of September to both groups were administered the Otis Test, the BSCS Impact Test, Watson-Glaser Test, Form AM, Nelson Biology Test, Form Am., and Hilliker's Biology Test, Form A. The results of these pretests were tabulated. A rescheduling of classes hindered a pairing of students as originally planned. The BSCS group was made up of honor and academic students, both boys and girls. The traditional group, all girls, was academic sequence. After the results of the Otis Test and the BSCS Impact Test were obtained eleven of the highest and five of the lowest ranking students were eliminated from the testing statistics. This was done to make the two groups more compatible as regards ability. This left fifty in each group.

Upon completion of the pretests the BSCS group commenced their year with the new textbook, **Biological Science-Molecules to Man.** The investigations compiled for use with this text were pursued during the laboratory periods, and consumed much more time than those of the traditional laboratory periods. The traditional biology group used the regular textbook, **Biology, the Study of Living Things,** Braungart and Buddeke. Their laboratory work consisted of using the microscopes, studying living specimens of animals and plants, models, films, and the usual type of dissection. The BSCS group used the BSCS tests, and the traditional group were given teacher-made tests.

In May, four post-tests were given. Form BM of the Nelson Biology Test, and Form B of the Hilliker Biology Test were used. It was not possible to get another form of the Watson-Glaser, and the BSCS Impact Test. The students were unaware they were to have the same forms of these tests and neither had been discussed with them. In June, the point hour ratios of the students tested were secured from the students' records. A t-score was obtained from this data. Since the results of the I.T.E.D. given in September were available t-scores for Natural Science Background, Reading in Natural Science, Quantitative Thinking, and the Composite were worked

out. This battery of tests is considered definitely superior as a testing instrument. These tests attempt to test ability to obtain and use knowledge, as well as the amount of knowledge the students have already obtained.

In the Otis Test, eighty-six per cent of the BSCS group's I.Q. scores were between 111 and 128, while those of the traditional group were between 102 and 122. The latter group had no score higher than 122, while the BSCS group had fifteen students whose scores were higher. The BSCS group had no score below 100, and the traditional group had fourteen students with I.Q.'s below. The BSCS group had the advantage of mental ability, but the writer has seen students with high intelligence who did not achieve as well as those of a lower mental ability.

These groups had had no science in high school except the three weeks of sophomore biology taken before the I.T.E.D. were given: A t-score was computed on the difference between the means of the two groups in four areas. The BSCS group had a mean score 5.28 points higher on Background in the Natural Science. This difference gave a t-score of 1.6003 which is significant at the 10 per cent level. On Interpretation of Reading in the Natural Science there was a difference of 7.40 in the mean scores favoring the BSCS group. The t-score of 1.881 is significant at the 5 per cent level. For Quantatitive Thinking the difference of 5.78 again favored the BSCS group. The t-score of 2.1213 is significant at the 5 per cent level. The means of the Composite scores differed by 6.92 points favoring BSCS. The t-score of 1.6307 is not significant. However, it would be at the 10 per cent level. The point hour ratios of the BSCS group were higher than those of the traditional group. Eighty-eight per cent of the BSCS group's point hour ratios were between 2.3 and 3.7, wihle seventy-six per cent of the traditional group's were between 2.0 and 3.1. Eight per cent of the BSCS group were between 3.8 and 4.0 while the other group had none. The t-score 1.5307 was not significant but it would be at the 10 per cent level.

In Table 1, a comparison of the results of the BSCS Blue Version and traditional biology groups study is shown. The two biology tests, Nelson and Hilliker, favoring more biology of the traditional type showed little difference in the increase of the means between the pretest and the post-test taken by the two groups. The BSCS Impact Test favoring the BSCS biology group, gave these students an increased means between the pretest and post-test which was twice that of the traditional group. At first this looked favorable for the hypothesis. On the Watson-Glaser Test the BSCS increased its means 2.2 times that of the traditional group. In order to adjust for individual differences the I.Q., the pretest and post-test results of four tests namely, Nelson Biology, Hilliker's General Information in Biology, the BSCS Impact and the Watson-Glaser Critical Thinking Appraisal were used in the analysis of covariance to obtain the final results of the study. The analysis of covariance provides tests of significance for the comparison of groups whose members have been measured with regard to one or more variable characteristics. It is frequently used when testing hypotheses pertaining to the differences in academic achievement. The formula used for the analysis of covariance in this study can be found by referring to Wert, Neidt, and Ahmann's book, **Statistical Methods in Education and Psychological Research.** After hours of calculating, the F-values were found, and then an adjustment was made of the means to

TABLE 1

COMPARISON OF THE BSCS BLUE VERSION BIOLOGY AND TRADITIONAL BIOLOGY GROUPS

Criterion	Subgroups of Biology	N*	$\bar{X}_1$*	$\bar{X}_2$*	$\bar{Y}$*	SS Adjusted for $\bar{X}_1$ and $\bar{X}_2$ Total	Within	F (df.1/96)	Level of Signifi-cance	Adjusted Criterion Means
Nelson	BSCS	50	118.10	108.62	119.46					111.61
Total	Trad.	50	107.16	98.62	107.78	3796.55	2791.73	107.42	.01	125.61
Hilliker	BSCS	50	118.10	43.42	57.86					51.33
Total	Trad.	50	107.16	35.04	49.00	2346.64	907.36	141.79	.01	60.54
Impact	BSCS	50	118.10	25.40	30.16					20.85
Total	Trad.	50	107.16	20.68	22.76	2416.98	2271.37	6.150	.05	23.13
Watson-Glaser Critical Thinking Appraisal	BSCS	50	118.10	64.14	69.06					64.94
Total	Trad.	50	107.16	57.54	59.78	4334.85	4173.84	3.7031	.10	60.47

* N – Number of students in each subgroup
$\bar{X}_1$ – Subgroup mean Genne I.Q.
* $\bar{X}_2$ – Subgroup mean on Pretest
$\bar{Y}$ – Subgroup mean on post-test

MEET OUR ADVERTISING EDITOR:

An active biology instructor, Sister Martina is shown discussing dihybrid crosses in genetics.

Although Sister Mary Martina, CHM, has been known to say that its a "man's world", she has found an important place in it. As biology instructor at Dowling High in Des Moines, and Chairman of the Science Department there, she is busy almost 24 hours a day.

Sister Martina was born in Albia, and attended school at Lovilia and Ottumwa. Being fond of the outdoors all her life, she especially enjoyed caring for sick small animals. "Surprisingly," she says, "these animals would regain their health. One in particular was so carefully tended that she gained enough to be sold with the others at the time of shipping. My father bought me a new dress as a reward."

Since 1930, when Sister entered the religious life, she has taught at Oxford, Centerville, Dunlap, and Des Moines.

After serving as Secretary of the IOWA SCIENCE TEACHER'S ASSOCIATION in 1964-65, Sister Martina assumed the immense task of Advertising Editor. Much of the success of our advertising program is due to her undying effort in working with scientific supply houses who place ads in the JOURNAL.

A recent tour of the eastern part of the United States was taken by Sister Martina and Sister Mary Jeanette.

find the true means which give a truer picture of the results.

The results are shown in Table I. After adjusting the means of the Nelson and Hilliker Tests, both of which lean toward the traditional side, there was a real difference between the true means. It was presumed that the traditional group achieved better than the BSCS group on these two tests.

On the Watson-Glaser, the BSCS group, after the adjustment of the means was made, had a higher mean than the traditional group. indicating they did better in the development of critical thinking.

On the BSCS Impact Test, the traditional group seemed to have achieved better than the BSCS group after the adjustment of the means was made The difference between the means of the two groups on this test was much less than on the other two biology tests.

The results of this study were discussed with others in the educational field. One teacher who had made a similar study thought that some of the students of the BSCS group were already high on the pre-test of the BSCS Impact Test and didn't increase on the post-test as much as students of the traditional group. Some of the others thought the "halo" effect might have spurred the students of the traditional group to put forward their best efforts.

It is recommended that this study be repeated with more classes participating and with more than one teacher involved, before a statement can be made affirming the superiority of one method over that of another method of teaching. Furthermore, it is recommended that new evaluation instruments in biology involving scientific inquiry be prepared and a new evaluation instrument for measuring critical thinking ability be constructed.