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After standardized testing of high-ability science students who were participants in a National Science Foundation Summer Science Institute, there is evidence to indicate that their understanding of science intangibles is dependent upon the section of the program in which they were enrolled. The participants in the mathematics and biochemistry sections demonstrated significantly better understanding of science.

Paul DeHart Hurd suggests that developments in science education should be influenced concomitantly by changes in society and new advancements in science in order to develop a "literate citizenry" in science. Therefore, one of the specific goals of science education today must be to produce scientifically literate citizens who "know something of the role of science in society and appreciate the cultural conditions under which science thrives".[1]

Pella, O'Hearn, and Gale suggest that an understanding of the " . . . nature of science, the ethics that govern the scientist in his work, the interaction of science and society . . ." are also necessary to have a "scientifically literate individual."[2]

If these characteristics are indicative of a "scientifically literate individual," and not just a person's accumulation of scientific knowledge (facts), the opportunity for further development of these characteristics was incorporated into the objectives for two National Science Foundation Summer Science Institutes for high school students at The University of Iowa.

These NSF Institutes have been sponsored by The University of Iowa for several years with the participants being either in the Research Program or in one of the subdivisions of the Summer Science Training Program.

For the Research Participation Program, the opportunity to develop these above characteristics was incorporated into three of the specific program objectives which were:[3]

(1) to stimulate superior students by familiarizing them with the daily activities of the scientist;
(2) to supplement usual high school activities in science with some real experience in scientific research;
(3) to demonstrate the nature of scientific research by providing first-hand experience in research laboratories under the guidance of research scientists.

Two of the major objectives included in the Summer Science Training Program Handbook (hereafter referred to as Course-Centered)

which were designed to further develop the above characteristics were:[4]

(1) to provide an opportunity for high-ability secondary students to work closely with active scientists as they study further in the areas of science not usually available in the high school or early college curricula;

(2) to provide high-ability students with insight as to how scientists work, where they work, and what they are like as persons.

Since the opportunity to develop the above characteristics was included in the Institute's objectives, it seems desirous to determine whether the participants in these two programs would, as a result of their interactions with scientists at the University, change in their understanding of science as a result of modifications in the above characteristics. This assumes that the programs were intended to assist in the production of "scientifically literate individuals."

Program Descriptions

The Course-Centered Program was subdivided into three areas: (1) mathematics, including abstract algebra and computer mathematics; (2) biochemistry, including organic chemistry and molecular biology; and (3) earth science, including field geology and meteorology with their activities being centered around the classroom. They also had the opportunity to share in formal seminars in which a staff member of a science department described research activities in his respective area and the opportunity to tour research facilities at the University.

The research participants had no formal classroom work, but were involved primarily in research activities in a laboratory with a research scientist. They also attended the above-mentioned formal seminars, experienced other research facilities at the University other than the one in which they worked, and met once a week for an evening "Scientific Enterprise" course which dealt with a humanistic examination of the intellectual products of scientific inquiry and the processes by which they are obtained.[3] At the termination of this program, each research student presented orally a summary of his summer research activities in a symposium.

Both groups lived together in a University domitory and were encouraged to freely interact about their courses, research activities, and other things of interest.

Experimental Procedure

The criterion instrument used in this study, the *Test On Understanding Science* of TOUS, was developed by two investigators to evaluate a students' understanding of science and scientists, the intangible aspects of science. There are three major areas of emphasis in the sixty-question multiple choice TOUS test:[5]

(1) Understanding of the scientific enterprise—(Test 1)

(2) Understanding about scientists—(Test 2)

(3) Understanding of the methods and aims of science—(Test 3)

Each group received the pre-test the first day that they arrived for the institute; the post-test was administered five days prior to the termination of the institute in order that the post-test would not interfere with some of their final course tests and presentation of their activities in the symposium.

Hypotheses

The hypotheses, stated in the null form:

(1) The Course-Centered Program (earth science) does not produce significant increases in students' understanding of science as measured by the TOUS test.

(2) The Course-Centered Program (biochemistry) does not produce significant increases in students' understanding of science as measured by the TOUS test.

(3) The Course-Centered Program (mathematics) does not produce significant increases in students' understanding of science as measured by the TOUS test.

(4) The research program does not produce significant increases in students' understanding of science as measured by the TOUS test.

Discussion and Summary

One of the requirements for participation in the course program was that the students were to be enrolled in a secondary school with low enrollment. This was evidenced by the core group having as their average class size seventy classmates. This same restriction was not placed upon the research students as evidenced by their average class size of 363 class members.

If a geographical distribution were considered, the core-program had forty-three Iowa residents and twenty-four out-of-state students; the research group had nine Iowa residents and thirteen out-of-state participants.

The average age was 17 years old and all the participants would have been seniors in high school starting in September, 1966.

Table 1 illustrates the average gain in raw test scores for each group with the mathematics and biochemistry sections achieving the best overall gains.

It might be thought that the research group would do better than the others in the test results in that they were more closely allied to a scientist and his activities, and as a result, would be more familiar with the aspects as tested in each of the TOUS subtests.

Perhaps due to specific students' previous high school science backgrounds or other experiences, the groups may start out with a distinct advantage in one or more of the subtest areas. Another thing to consider is that these are high-ability science students; this may have a definite influence on the results. To explore this possibility would necessitate having another group of students exposed to the same activities for a comparable length of time. The length of time necessary to modify student characteristics with reference to their understanding of science may vary from section to section. Perhaps the eight-week institute was not long enough to elicit a significant gain for the earth science and research groups.

Table 2 indicates that this idea was not substantiated, but that the mathe-

Table 1

TOUS Test Raw Scores on Pre- and Post-Tests with Average Gains Indicated for the Respective Groups

Group	N	Average Raw Score Post	Pre	Average Gain
Earch Science	14	40.07	39.64	0.58
Mathematics	25	39.92	37.20	2.80
Biochemistry	28	41.25	38.85	2.39
Research	22	41.18	41.77	0.68

Table 2

TOUS Subtest Gains
(See Text for Description)

Group	Test 1	Test 2	Test 3
Earth Science	0.85	0.07	–0.28
Mathematics	0.64	0.89	1.96
Biochemistry	0.92	0.53	0.67
Research	–0.54	–0.45	0.88

matics and biochemistry sections did better.

To find possible explanations for this is difficult and only speculative at best. One suggestion may be found in the suggestions by Dressel and Mayhew.[6] The "ceiling effect" may be in operation for these students such that their initially high scores have a reduced possibility for gain. Or the "regression effect" may be in operation such that the initially high scores drop rather than gain.

The initially high scores of the groups according to the standardized results for the 11th graders from the TOUS Manual correspond to the 91st and 92nd percentiles.

Table 3 identifies those groups that demonstrated significant gains in test scores. From these results, we will have to reject the null hypotheses for the mathematics and biochemistry sections and accept the other two.

Table 3

t-Test Results of TOUS Raw Scores at 0.05 Level of Significance

Group	
Earth Science	Not significant
Mathematics	Significant
Biochemistry	Significant
Research	Not significant

The results of this study of the 1966 Summer Program will have to be compared to those of the 1967 Program which are still being computed. A follow-up study will compare these two programs.

FOOTNOTES

1. Hurd, Paul DeHart, 1964. Theory Into Action. National Science Teachers Association, 9.
2. Pella, M. O., O'Hearn, G. T. and Gale, C. W., 1966. Referents to Scientific Literacy. Journal of Research in Science Teaching, IV.
3. Yager, Robert E., 1966. Research Participation Handbook. The University of Iowa.
4. Yager, Robert E., 1966. Summer Science Training Program Handbook. The University of Iowa.
5. Cooley, W. W. and Klopfer, L. E., 1961. Manual for the Test On Understanding Science, Educational Testing Service, Princeton.
6. Dressel, P. L. and Mayhew, L. B. *General Education: Exploration in Evaluation.* Washington, D.C. American Council of Education. 1954.