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ABSTRACT

This study examines the role of a 6- or 8-week summer university laboratory internship for 56 high ability secondary students in developing the views of these students with respect to the nature of science. Students were assessed using a gender-neutral version of the Test on Understanding Science (TOUS) as part of a pretest-posttest research design. Results indicated no significant change from pretest to posttest on any of the subscales of this test. When all the variables were analyzed, only the internship duration (6-week versus 8-week) showed a significant change. The 8-week group made a significant gain in understanding about the scientific enterprise. The TOUS did not perform well in assessing this population. Although the posttest reliability, measured by KR-20 was a respectable 0.66, the mean difficulty was a high 69.30 and the mean discrimination was only 0.23. These values may be explained by the generally high level of pretest achievement and the overall homogeneity of the students. The accompanying qualitative study indicates that students gained much with respect to understanding the nature of science, but the TOUS is clearly not the best instrument to use in substantiating that finding. (PR)

The Effects of An Intensive Summer Laboratory Internship on Secondary Students' Understanding of the Nature of Science as Measured by the Test on Understanding Science (TOUS)

Paper presented at the 66th annual meeting of the
National Association for Research in Science Teaching
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Abstract

This study, a companion to a qualitative investigation by McArthur (1993), examines the role of a six or eight week summer university laboratory internship for high ability secondary students in developing the views of these students with respect to the nature of science. Students were assessed using a gender-neutral version of the Test of Understanding Science (TOUS)(Form W) as part of a pretest-posttest research design. The TOUS provides a total score and three subscales (understanding about the scientific enterprise, about scientists and about the methods and aims of science). Although the TOUS is not directly aligned with instruction it was applied as a measure of the degree to which students are able to transfer aspects of their laboratory internship to an understanding of science in general.

The overall TOUS scores showed no statistically significant change, from pretest to posttest, nor were any significant changes seen with respect to any of the subscales. When all other variables were analyzed (e.g. ethnicity, number of science classes completed, gender, length of internship or academic average, and internship duration) only the internship duration (six week versus eight week) showed a significant change. Multiple regression and covariance techniques demonstrated that the eight week group, although statistically identical with the six week group on the overall pretest, did make a significant gain ($p < .05$) at the posttest level on subscale I (understanding about the scientific enterprise). No other significant changes were noted in the subscales.

The TOUS itself did not perform well in assessing this population. Although the posttest reliability, measured by KR-20 was a respectable 0.66, the mean difficulty was a high 69.30 and the mean discrimination was only 0.23. These values may be explained by the generally high level of pretest achievement and the overall homogeneity of the students. The accompanying qualitative study indicates that students have gained much with respect to the nature of science by working as laboratory interns, but the TOUS is clearly not the best instrument to use in substantiating that finding.

Purpose of the Study

The purpose of this study is to examine the extent to which an intensive summer laboratory internship communicates aspects of the philosophy of science to a group of 60 high-achieving secondary school students as measured by the Test of Understanding Science (TOUS) and its three scales.

Significance of the Study

The nature of science is one of the major areas targeted for inclusion in school science curricula by principal current science education reform efforts, Project 2061: Science for All Americans (AAAS, 1989) and Scope Sequence and Coordination from the National Science Teachers Association (NSTA, 1992), in the newest national assessment of educational progress (NAEP) and in the proposed national standards for science education. Cossman (1989) conducted a detailed review of philosophy of science issues contained in the NAEP items and in the Project 2061 objectives. Both NAEP and Project 2061 contain objectives suggesting that students should be familiar with scientific observation, methods of science, data interpretation, support and refutation of scientific ideas, hypothesis generation, the tentative nature of scientific ideas and the character of the community of scientists.

Although not featured as prominently as in Project 2061, the Scope, Sequence and Coordination reform effort also suggests that the nature of science is an important ingredient in the reform of science instruction. In addition, the new National Standards for Science Education will include issues related to the philosophy of science as learning goals.

Students should "develop an understanding of the nature of scientific inquiry . . ." "as a model of how we know what we know in science" (National Research Council, 1993, p. 55).

In spite of recommendations to include philosophy of science issues in the curriculum, none of the sources cited suggest a mechanism by which such recommendations may be put into place. The core issue is how to address and communicate recommended aspects of the philosophy of science most effectively. The significance of this study lies in its potential to show that a student working as an intern in a research laboratory may actually *learn about* the nature of science while *doing* science. As the number of science internships and related experiential programs increases, either through summer institutes for high ability students or through academic year mentorships for students of average ability (Waltner, 1992) -- it becomes increasingly important to assess exactly what students gain from such experiences. This study reported here attempts to shed light on one of the anticipated outcomes from such programs -- an increase in the level of knowledge regarding the nature of science.

Goals of the Study

The following are the principal areas of investigation with respect to high-ability secondary school students participating in a summer laboratory internship. To:

1) determine the degree to which high-ability students understand the nature of science as measured by the TOUS.

2) explore indicators of the role that a summer laboratory internship experience may play in altering students' knowledge of the philosophy of science.

3) investigate the role played by other factors (gender, internship duration, nature of the internship experience, etc.) in altering students' knowledge of the nature of science while participating in a laboratory internship.

4) study the TOUS instrument as an effective and reliable measure of the nature of science for high-ability students.

Design and Procedures of the Study

The Method

This study is a single group pretest-posttest (Campbell and Stanley, 1966); a pre-experimental design providing clues to causation. The criterion measure was provided by pretest-posttest administrations of the Test of Understanding Science (TOUS) (Cooley and Klopfer, 1961). The TOUS was administered as a pretest to students in each of the two groups upon their arrival on campus. The posttest was administered to the students several days before the completion of both the six week and eight week internships. In addition to the administration of the TOUS, information regarding a number of independent variables (academic grades, gender, number of science classes completed, duration of internship, etc.) was also collected.

It should be noted that the TOUS was designed to measure student's knowledge of the nature of science generally and is not, for that reason, aligned with the laboratory internship experience reported here. Any gains seen in TOUS scores from pretest to posttest would most accurately be attributed to transfer effects rather than direct instruction-related achievement.

The Sample

Sixty high ability secondary school students -- of whom 56 completed both the pretest and posttest -- were involved in the study during the summer of 1992 at a large midwestern research university. All students were "high-ability" based on measures including class rank, letters of recommendation, prior achievement, and other factors. Most students entered the summer internship program with a strong science background. However, only four students had actually experienced a similar laboratory internship experience.

Twenty students participated as a cohort in the laboratory internship for eight consecutive weeks; another group of forty students arrived two weeks after the first group began, participating for a total of six consecutive weeks. Both groups of students ended their internship experiences at the same time. Table 1 provides a summary of some characteristics of the students participating in the laboratory internship.

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While the details of the individual internship experiences varied, each student had daily contact with researchers in a university laboratory as they worked on some aspect of an on-going project. This contact included frequent interaction with research assistants and post-doctoral fellows but less frequent direct work with the principal investigator. Students operated primarily as laboratory technicians, but all participated in research meetings, were briefed by and reported to the principal investigator, and were required to make a final presentation at the conclusion of the internship by explaining the goals and results of their research experience. In addition to the general presentation required of all students, approximately 15 percent of the participants made presentations of the results of *original* research projects.

The Instrument

In spite of interest expressed by science education reformers and curriculum developers that an understanding of the nature of science be a part of students' educational experience, this domain has been generally neglected by designers of assessment tools. Consequently, the best single measure of student's understanding of the philosophy or nature of science remains the Test of Understanding Science (TOUS) developed in the early 1960's (Cooley and Klopfer, 1961).

The instrument is a 60-item multiple choice test providing a total score and subscores targeting knowledge of the scientific enterprise (I), the scientist (II), and the methods and aims of science (III). The characteristics of each of the subscores is outlined below (Cooley and Klopfer, 1963, p. 74).

Subscore I; Understanding about the scientific enterprise (18 items)

1. Human element in science
2. Communication among scientists
3. Scientific societies
4. Instruments
5. Money
6. International character of science
7. Interaction of science and society

Subscore II; Understanding about scientists (18 items)

1. Generalizations about scientists as people
2. Institutional pressures on scientists
3. Abilities needed by scientists

Subscore III; Understanding about the methods and aims of science (24 items)

1. Generalities about scientific methods
2. Tactics and strategy of sciencing
3. Theories and models
4. Aims of science

5. Accumulation and falsification
6. Controversies in science
7. Science and technology
8. Unity and interdependence of the sciences

Cooley and Klopfer (1961) report an overall reliability (KR-20) of 0.76 with KR-20 scores for the subscales ranging from 0.52 to 0.58 with a large heterogeneous group of secondary students.

Although the TOUS is generally accepted as the most effective instrument available, it has not escaped criticism even at the time of its development. Grobman, writing in Buros (1972), states that one of the items designed to find out how much students know about the direction of science in America may be problematic since the most appropriate response varies depending upon changes in politics and perceived national goals. Wheeler (1968), Welch (1969), Noll (in Buros, 1972) and Aikenhead (1973) have made related criticisms of the TOUS, but the frequency of its initial use and the paucity of other such instruments justifies the use of TOUS in the assessment of nature of science knowledge.

A reexamination of the TOUS instrument with respect to its use in this study revealed potential gender bias in a number of the items. For example, the word ***scientist*** in the original version (Form W) is frequently linked with the personal pronoun ***he*** or ***his***. Therefore, the TOUS (Form W) was rewritten slightly to minimize gender bias in those few items exhibiting such bias. The gender-neutral version Form W was applied in this study.

TOUS and Related Studies of the Impact of Investigative Teaching

During the height of its popularity, the TOUS instrument was applied in a number of studies primarily to examine the extent to which one teaching technique or another best communicated aspects of the philosophy of science to students. An examination of a number of studies showed that a teaching approach involving an integrated or inquiry / investigative component resulted in a significant positive difference in all or most subscores of the TOUS when compared with a "traditional" approach. Although it is difficult to determine precisely what is meant by a "traditional" approach, many researchers characterized it as a didactic, lecture-demonstration mode of teaching. Table 2 contains a summary of the results of a number of potentially-related studies in which the TOUS was applied.

Specifically, Sheppard (1969) demonstrated that junior high students taught using the Earth Science Curriculum Project (ESCP) -- an inquiry approach -- fared significantly better on all subscores of TOUS when compared with counterparts in "traditional" classes. Green (1972) with a similar study, showed that ESCP students performed significantly better than did "traditional" students, but only in subareas II (knowledge about scientists) and III (knowledge about the methods and aims of science).

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Mallette (1967), examining the junior high school integrated science project, Interaction of Matter and Energy (IME), demonstrated that there was a significant gain in TOUS scores when comparing the traditional and IME group. The students in the IME classes showing growth on the TOUS primarily in Subarea III (knowledge about the methods and aims of science).

Mallette's work is substantiated by Schlenker (1970) who found that grade 5-8 students involved in an inquiry-based physical science program achieved significantly better on the TOUS -- particularly in Subareas I (science) and II (scientists) when compared with students in traditional classes. Although these results indicate that an inquiry approach has a strong impact on an individual's knowledge of aspects of the nature of science other researchers such as Smith (1971), Stengel (1971) and Durkee (1974) examining investigative teaching approaches have not found such significant results. Durkee studied a population of high-achieving secondary school students in a summer physics internship much like those students examined here.

Results and Analysis

The results of this study fall into several categories; characteristics of the Test of Understanding Science itself for this group of students, an analysis of the TOUS scores, and a statistical examination of the contribution of certain independent variables to the overall TOUS variance.

Analysis of the Test Itself

Table 3 illustrates the reliability, mean difficulty and mean discrimination values for this administration of the TOUS instrument. Kuder-Richardson 20 reliability, measures indicate considerable variability ranging at the posttest level from 0.38 to 0.57 on the subscales, with an overall reliability of 0.66. One might expect the reliability to be higher for a professionally-designed test. However, the values established here correspond well with those reported by Cooley and Klopfer (1961) for a large (2425 students) heterogenous group used to norm the test originally.

Difficulty and discrimination measures how well an item distinguishes between those students who receive overall high scores and those who receive overall low scores. High positive discrimination (near +1.0) means that most of the high-scoring students chose the correct answer. The generally-accepted value for a test that discriminates well is +0.40 or better (Evaluation and Examination Service, 1992). The mean discriminations value for the posttest reported here was 0.23 and ranged from 0.26 to 0.36 on the posttest subscales.

The item difficulty index is a measure of the percent of students who answer the item(s) correctly. Normally, for test likes this, the ideal difficulty is 42.5% (Ebel and Frisbie, 1986). Average difficulties on the various posttest scales in the present study varied from 60.12 on one of the subscales, up to 76.11%. While both the mean difficulty and mean discrimination are outside the normally acceptable ranges for tests designed for general use, the computed indexes were expected given the rather homogeneous sample of high ability students.

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Student Knowledge of the Nature of Science

Table 4 summarizes the scores and standard deviations for the total TOUS and for the three subscales. Included for comparison are the results from the only other study of high-ability summer laboratory interns (Durkee, 1974). In addition, t-tests of significance are reported for the overall test and for each of the scales.

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Although the students in this study are high achievers generally, most secondary science curricula contain little about the nature of science and few instructors emphasize such issues. There, it was a surprise that students had such high mean scores at the pretest level; 68.67% correct overall with a range of 60.12% to 75.79% on the subscales. However, these results correspond well with those established for a similar student group by Durkee (1974). Furthermore, although the trend is an increase in knowledge regarding the nature of science, neither the data reported here nor those of Durkee (1974) illustrate a significant change from pretest to posttest.

The Contributions of Selected Learner-Related Characteristics

A number of independent variables were evaluated in an attempt to examine their role in students' knowledge of the nature of science. Variables such as gender, ethnicity, number of high school science classes completed, academic achievement and length of internship were analyzed with SPSS / PC+ 4.0 (Norusis, 1990) using two multiple regression techniques; stepwise addition and backward deletion. Only when the students are separated into groups associated with length of internship (6 weeks or 8 weeks in duration) do we see any significant difference. The gain in mean scores for subscale I (understanding about the scientific enterprise) is significant ($p < .01$) when comparing pretests and posttests (see Table 4). When examined using the regression technique that first evaluates the role of time-on-task in explaining variance, we find a significant, albeit weak, main effect attributable to internship duration.

To check the supposition that the 6 week students and 8 week students were already significantly different at the pretest level, thus accounting for the differences seen at the posttest level, an analysis of covariance was performed. While some differences do exist between the prestest scores of the 6 and 8 week groups, once those differences have been controlled by the use of the ANCOVA detailed in Table 5, the remaining variance is best accounted for by the time on task variable. The difference established by the analysis of covariance is significant at the .05 level.

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Discussion and Conclusions

With respect to the goals of this study, the following conclusions may be drawn. This group of high-ability students already possessed substantial knowledge about the nature of science before attending the laboratory institute. Subscale III (Understanding the Methods and Aims of Science) was the weakest at both the pretest and posttest levels. An examination of the individual items in this section reveals that the test authors generally targeted scientific methods in the construction of this subset. It may be that these students, if they have had typical school science experiences have performed verification rather than investigative laboratory activities and have not yet experienced real scientific inquiry. The lack of growth in this domain may be due to the brevity of the summer institute or to their limited role in the design of the project on which they worked. Equally interesting, however, are the high scores on the other subscales even before the start of the internship. There was a fairly high positive correlation between students' SAT_{verbal} scores and the TOUS results, so perhaps it is general reading and reasoning ability rather than true knowledge of the nature of science that best accounts for the high initial scores.

McArthur (1993) in her qualitative study of the same interns found that students did learn much about the nature of science through their summer experience. However, such a claim cannot be so clearly substantiated with the quantitative TOUS study reported here. This mismatch between findings -- while supportive of the role of joint quantitative-quantitative investigations -- is somewhat troubling.

The relative lack of growth seen in the TOUS scores reported here may be due to the nondiscriminatory character of the instrument itself and the ceiling effect related to the high pretest scores or it may be that this instrument is not the ideal tool to use in a study of this type.

Finally, the sole significant result, that the longer one works as a laboratory intern the more likely it is that growth in understanding will occur in the domain of knowledge regarding the scientific enterprise should be examined. If this is a valid result, it would be interesting to discover what aspects of the laboratory internship are responsible for the growth seen. Furthermore, if time-on-task is a factor in the increase in knowledge about any aspect of the essential character of scientific research, the logical recommendation would be to increase the length of time that students spend working in this arena.

Implications for Future Research

Aikenhead (1973), in an analysis of instruments used to measure students' knowledge about science and scientists has shown that several assessment tools have been developed to provide information about this domain. He indicates, for instance, that the Test on the Social Aspects of Science (TSAS) resembles Scale I of the TOUS. Given the indication that students participating in laboratory internships for longer periods do show statistically significant growth in Subscale I (understanding about the scientific enterprise), it would be useful to apply the TSAS in future studies of the effects of laboratory internships on students' knowledge of the nature of science or to establish the correlation between the TSAS and subscale I. An analysis on the individual items comprising the subscales to suggests explanations for the low discriminatory ability of the test, to provide clues explaining the high initial knowledge of the nature of science exhibited by the students or to restructure the test making it more effective as a assessment tool. Finally, the generally lackluster performance of the TOUS suggests that a new nature of science assessment instrument -- perhaps designed for students working in laboratory and field environments, should be developed. With a renewed emphasis nationally on authentic instruction, it is reasonable to assume -- and hope -- that larger numbers of students will be participating in internships as part of their school science experiences.

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Table 1. Characteristics of Students Attending a Summer Laboratory Internship

Independent Variable	Mean	Standard Deviation	Number of Students
Academic Average (percent)	95.79	4.43	56
Grade Completed	10.77	0.61	53
Number of Science Classes Completed	3.40	1.06	57

Independent Variable		Percent of Students Illustrating Characteristic
Gender	Male	47%
	Female	53%
Grade Completed	10	32%
	11	59%
	12	9%
Ethnicity	Native American	4%
	African American	5%
	Asian American	37%
	Caucasian American	46%
	Hispanic American	5%
	No Response	3%

Table 2. Summary of Studies Investigating the Effect of Inquiry Instruction on Students' Knowledge of the Nature of Science.

	Grade	Type	Scale I	Scale II	Scale III	TOUS Total
Mallette (1967)	Jr High Science	Int.	n.s.	n.s.	sig.	n/r
Kendall (1970)	11-12th Physics	Int.	n/r	n/r	n/r	sig.
Mackay (1971)	7-10th Science	Int.	n.s	n.s.	n.s.	n.s.
Sheppard (1969)	Jr High Science	Inv.	sig.	sig.	sig.	sig.
Green (1972)	Jr High Science	Inv.	n.s	sig.	sig.	n/r
Schlenker (1970)	5-8th Grades	Inq.	sig.	sig.	n.s.	n/r
Smith (1971)	College Biology	Ext.	n.s.	n.s.	n.s.	n.s.
Durkee (1974)	Physics Lab Int	Sum.	n.s.	n.s.	n.s.	n.s.

Int. = Integrated vs. Traditional
Inv. = Investigative (ESCP) vs. Traditional
Inq. = Inquiry vs. Traditional
Ext. = Extended vs. Traditional Labs
Sum. = Summer Physics Lab Internship

n.s. = No Significance sig. = Significance n/r = not reported

Table 3. TOUS Test Statistics for a Group of High Ability Secondary School Student in a Summer Laboratory Internship

Test	# of Items	Reliability KR-20		Mean Difficulty		Mean Discrimination	
		PRE	PST	PRE	PST	PRE	PST
Scale I	18	0.48	0.38	72.94	76.11	0.32	0.29
Scale II	18	0.22	0.57	75.67	75.50	0.27	0.36
Scale III	24	0.53	0.44	60.04	60.12	0.29	0.26
TOUS Total	60	0.64	0.66	68.63	69.30	0.21	0.23

N = 57

Table 4. Pretest and Posttest TOUS (Form W) Scores for a Group of Summer Laboratory Intern Students with t-Tests.

		Pretest		Posttest		t	p
		Mean (%)	S.D.	Mean (%)	S.D.		
Scale I	6 wks[a]	70.50	13.26	72.74	11.25	-1.125	n.s.
	8 wks[b]	78.71	12.55	84.53	8.64	-2.593	<.01
	Total[c]	72.95	13.49	76.26	11.79	-2.125	n.s.
Scale II	6 wks[a]	75.40	10.54	74.90	14.79	0.235	n.s.
	8 wks[b]	76.35	11.22	77.12	10.94	-0.301	n.s.
	Total[c]	75.79	10.43	75.56	13.70	0.137	n.s.
Scale III	6 wks[a]	60.00	12.29	58.45	10.93	0.843	n.s.
	8 wks[b]	60.41	13.75	64.88	13.36	-1.775	n.s.
	Total[c]	60.12	12.62	60.37	11.96	-0.161	n.s.
Total TOUS Test	6 wks[a]	67.78	8.25	67.73	8.79	0.036	n.s.
	8 wks[b]	70.77	10.59	73.47	8.62	-1.873	n.s.
	Total[c]	68.67	9.02	69.44	9.06	-0.726	

[a] Degrees of Freedom = 39
[b] Degrees of Freedom = 17
[c] Degrees of Freedom = 56

6 wk = Scores of summer internship students participating for 6 weeks
8 wk = Scores of summer internship students participating for 8 weeks
Total = Scores of all summer internship students

Table 5. Analysis of Covariance for Posttest Scores by Time on Task with Pretest Scores

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Covariates Pretest	668.731	1	668.731	38.842	0.000
Main Effects Time on Task	69.074	1	69.074	4.012	0.050
Explained	737.804	2	368.902	21.427	0.000
Residual	929.705	54	17.217		
Total	1667.509	56	29.777		