PHYS-MA-TECH: An Integrated Partnership

Jule Dee Scarborough & Conard White

There is a national movement across the U.S. to reform education, especially for students of average ability and school achievement–the "forgotten majority". Curricular integration across disciplines using teacher teams to broaden learning contexts as well as improving access to academic courses such as physics and mathematics has been a response to the call for reform (see, for example, American Chemical Society, 1988; Benson, 1989; Bottoms, 1989; Edgerton, 1990; Grubb, Davis, Lum, Plihal, & Morgaine, 1991).

There is an increasing amount of literature on the subject of integration, especially literature that describes particular programs and curricula such as Principles of Technology (Center for Occupational Research and Development and the Agency for Instructional Technology, 1986), Tech Prep (Key, 1991), Science-Technology Society (Aiken, 1992), and Project 2061 (Johnson, 1989). However, little research is available regarding the simultaneous integration of physics, mathematics, and technology through interdisciplinary teams and the resulting impact that such an approach has on learning physics.

Most integration endeavors have involved either coordinating curricula or having teachers working cooperatively to reinforce concepts so that learning transfers across two or more contexts. These activities are important steps towards improving education, but possibly a stronger and more substantial approach would entail activities that actually restructure the organization and delivery of content across disciplines, including nontraditional teacher assignments as well as nontraditional teaching methodology.

The PHYS-MA-TECH project was funded by the National Science Foundation, the Illinois State Board of Education, and Northern Illinois University. The goal of the project was to improve high school physics by integrating Physics/Mathematics/Technology (P/M/T) both in content and delivery of instruction. It was proposed that average students have an untapped ability in physics and mathematics. Their potential in these areas cannot be projected merely on the basis of past performance. A basic assumption of this study was that average students can not only perform at an acceptable level in physics, but also possibly do better if it is taught in a relevant fashion. In addition, it was felt that average students of the "forgotten majority" may not be getting access to important science and mathematics courses. It also seems that many integra-

Jule Dee Scarborough and Conard L. White are Professors in the Department of Technology, Northern Illinois University, DeKalb, IL.

tion activities have fallen short in addressing the real issues that must be considered before integration can be sustained for any length of time.

The researchers hypothesized that (a) average students who do not take physics *are* interested in the subject, (b) they *can* succeed in physics, and (c) P/M/T integration in content and delivery *will* provide a better route for such students to learn physics.

The study sought to measure the effectiveness of the PHYS-MA-TECH program by seeking answers to the following research questions:

1. Is there any difference in intellectual ability and academic achievement between average students "who would not normally enroll in physics" and those enrolled in a regular physics course?

2. Is there any difference in gain in physics achievement between students enrolled in the PHYS-MA-TECH course and those enrolled in a regular physics course?

Procedure

Letters were sent to fifty school superintendents in northern Illinois describing the project and inviting them to participate. Twelve school districts responded with definite interest and six additional districts were interested in exploring the possibility further.

After an orientation meeting with the superintendents, five schools were identified to participate in the study. These schools represented a broad range of socioeconomic communities, student population (ability, race, ethnicity), and geographic location (rural/suburban/urban).

A team of three teachers (one physics, one mathematics, and one technology teacher) was established at each participating school. After going through a rigorous process of inservice activities, the teachers worked as a group to establish acceptable content for a one-year, standard, high school physics course. The course was analyzed for prerequisite mathematics and a potential technological framework within which physics could be taught. The teams then developed an integrated PHYS-MA-TECH curriculum which included 45 modules.

Each school selected a sample of modules to field test. Each module was field tested by two or more schools. The modules were then revised based upon field-test results and used for the study. They are now available to teachers under the name PHYS-MA-TECH.

Subjects

The study sought to insure that the students chosen to participate were “average” high school students rather than advanced placement or “high achievers.” Each of the schools identified one or more classes of students to enroll in the PHYS-MA-TECH course and were defined as the experimental group. The students were selected by teachers and counselors on the basis of those who “would not have taken physics.” At least one section of regular placement physics was selected in each school to serve as a control group. General intelligence scores and overall grade point averages were collected for each student in the sample. As each school did not use the same test of general intelligence, percentile scores were employed in the data analysis. Table 1 reports IQ percentile scores for the experimental and control groups. A *t* test indicated that no significant difference existed.

Table 1
IQ Percentile Scores by Treatment Group

	n	Mean	SD	*df*	*t*	*p*
Experimental Group	43	65.28	22.12			
Control Group	75	72.01	18.65	116	-1.76	0.081

Table 2 reports the mean grade point averages (4-point scale) between the experimental and control groups. Examination of the *t* test results indicated that students in the control group had a significantly higher grade point average than those in the experimental group

Table 2
Overall Grade Point Average by Treatment Group

	n	Mean	SD	*df*	*t*	*p*
Experimental Group	43	2.40	0.59			
Control Group	75	2.86	0.61	116	-4.03	<.01

Since the subjects in the control group had higher grade averages, but equal IQ percentiles, one might conclude that students “who do not normally enroll in physics” are of equal ability but do not perform as well in school as those who do.

Development of the Instrument

During the developmental phase of the program, project teachers adopted a course outline for a typical high school level physics course from one developed by the American Association of Physics Teachers (AAPT) and the National

Science Teachers Association (NSTA). This outline was used as a guide in the development of the PHYS-MA-TECH modules, (experimental), and the regular physics course, (control). To assess achievement in the experimental and control groups, the Physics Achievement Test was developed.

The major portion of the Physics Achievement Test was extracted from an achievement test developed by the AAPT/NSTA in conjunction with the course outline described above. Since the achievement test was developed from the course outline, this helped to assure that each of the content areas in the outline would be assessed. Additional test items were developed by the project teachers to assess the additional mathematics and technology concepts included in PHYS-MA-TECH modules.

The Physics Achievement Test consisted of 95 multiple-choice items, each of which had either four or five responses. The test was divided into five unit tests, each coordinated with one of the five major units of instruction. The unit tests were: (a) Mechanics, 34 items; (b) Heat and Kinetic Theory, 17 items; (c) Electricity and Magnetism, 22 items; (d) Waves, Optics, and Sound, 17 items; and (e) Modern Physics, 5 items. The number of items in each unit reflected the proportion of instructional time allotted to them.

Since a large portion of the Physics Achievement Test was developed from the adopted course outline by the AAPT/NSTA, it was assumed that the test would be valid for measuring each of the content areas in the course outline. To augment test validity, a copy of the course outline and each of the test items arranged in a random order was analyzed by a group of five high school physics teachers. They were asked to: (a) select the appropriate content area from the course outline which the item measured, (b) point out any items which were ambiguous, and (c) choose the correct answer for the item. Upon completion of these activities, the instrument was finalized and printed.

The study was conducted during the 1990-91 school year. During the first two weeks of the school year, the unit test for the first unit of instruction (Mechanics) was administered. As each of the five major units of instruction was completed, the physics subtest for the unit just completed was administered as a posttest and the subtest for the unit which was about to begin was administered as a pretest. The tests were administered by project staff and were not seen by the participating teachers to insure that classroom instruction was not "geared" specifically to test items.

Results

Table 3 displays the overall test results of the Physics Achievement Test by treatment group. The number of items correct is displayed in each cell. The raw gain cells depict the mean differences between individual pretest and posttest scores. Residual gain scores were calculated to serve as a dependent variable to indicate an increase in learning from the pretest to the posttest. A regression analysis was completed using the pretest score on each unit test as a predictor of the unit posttest score. Each of the correlations between pretest and posttest was found to be highly significant. The regression weights were then used to calculate a predicted posttest score from the pretest score. The difference between this predicted score and the student's actual posttest score is the residual gain.

Table 3
Physics Achievement Test Scores: Pretest, Posttest, and Gain Scores by Treatment Group

Group	Unit Test Mech.	Heat	Elect.	Waves	Modern Physics	Total Scores
Experimental						
n = 43						
Pretest	9.33	5.26	6.84	4.14	1.72	27.28
Posttest	11.86	6.44	8.14	4.67	1.88	33.00
Raw Gain	2.53	1.19	1.30	0.53	0.16	5.72
Residual Gain	-0.34	-0.41	+0.00	-0.42	-0.08	-1.25
Control						
n = 75						
Pretest	10.52	6.80	7.55	4.00	1.72	30.59
Posttest	13.08	7.80	8.41	5.28	2.01	36.59
Raw Gain	2.56	1.00	0.87	1.28	0.29	6.00
Residual Gain	+0.19	+0.24	-0.00	+0.24	+0.05	+0.72

To serve as a basis for comparison between treatment groups, a two-way multivariate analysis of covariance was utilized to test for differences in mean pretest scores. Student scores on the five physics subtest scores were used as dependent variables. The independent variable was treatment group. IQ percentile score and student grade point average were used as covariates to control for student ability and previous performance in school.

Table 4 reports the results of the multivariate analysis on the pretest data. The value for Pilliai's Trace, a multivariate statistical treatment, has been transformed to a statistic which has an approximate F distribution. The significance level for this F is shown in the table.

Table 4
Multivariate Analysis of Variance Table for Physics Pretest Scores by Treatment Group

	Multivariate Tests of Significance				
Effect	Pilliai's Trace	Approx. F	*df*	Error *df*	Prob.
Within Cells	0.34	4.55	10	222	0.000
Treatment Group	0.06	1.44	5	110	0.217
Constant	0.18	4.73	5	110	0.001

The *Within Cells* effect indicates that the covariates, IQ and GPA, are significantly related to the dependent variables. This covariate effect is removed prior to testing for the remaining effects, thus controlling for IQ and GPA.
The *Treatment Group* main factor was not significant. This indicates that there was no significant difference in mean pretest scores between the experimental and control groups. Table 3 shows that the control group had an overall mean of 30.59 correct items as compared with 27.28 for the experimental group.
The *Constant* effect indicates that the grand mean of 29.38 correct items was significantly different from zero.

Gain in Physics Achievement
A multivariate analysis of covariance was also utilized to test for a significant difference in mean residual gain between treatment group. The mean residual gain score between pretest and posttest administrations of the physics achievement was used as the dependent variable. These data are reported in Table 3.
Table 5 contains the multivariate analysis of variance for residual gain of the five unit tests between treatment groups. As with the previous analysis, IQ and student grade point average were used as covariates.
The *Within Cells* effect was significant, thus indicating that the covariates, IQ and GPA, were related to the residual gain. This effect was removed before the other factors were taken into consideration. As can be seen from Table 5,

Table 5
Multivariate Analysis of Variance Table for Physics Residual Gain Scores by Treatment Group

	Multivariate Tests of Significance				
Effect	Pilliai's Trace	Approx. F	*df*	Error *df*	Prob.
Within Cells	0.22	2.71	10	222	0.004

Treatment Group	0.02	0.44	5	110	0.822
Constant	0.15	3.79	5	110	0.003

the *Treatment Group* main factor effect indicates that there was no significant difference in mean residual gain between the experimental and control groups.

Discussion

This project seems to be one of the first involving technology educators funded by the National Science Foundation. Because the goal of the project focused on improving physics, some have questioned its implications for technology and vocational education. Rather than question the value or relationship of this project to our fields, perhaps focus should be placed on the positive outcomes. Students selected for this study would not have enrolled in a physics class on their own volition. Although they displayed intellectual abilities equal to those who normally enroll in physics, their achievement levels were found to lag behind. When physics was taught using an integrated approach, these students exhibited a similar gain in achievement as those enrolled in a regular physics class. This suggests that the integration of physics, mathematics, and technological content provides a valuable teaching tool for helping students grasp subject matter which they might have previously felt was either beyond their reach or was uninteresting.

In addition to the outcomes supported by research data that serve to stimulate repositioning of technology education, or perhaps vocational education, in relationship to physics education, the reader should consider the related outcomes as well. Five schools, after participating in this project, have committed to long-term integration of P/M/T in both content and delivery. Four of these schools have sustained the models and have gone well beyond the integrated course(s) that resulted from the project development and field testing. One school is planning to develop four years of integrated science, mathematics and technology, one course for each grade level. Another school has added a second class of integrated P/M/T and began other integration initiatives while a third school has developed a capstone engineering course using the P/M/T approach. This school also has an integrated physical science course for ninth-grade students taught *collaboratively by science and technology teachers*.

Finally, another school is utilizing a technological approach for accelerated physics and has introduced an integrated ninth-grade physical science course. Three schools have reported that enrollments in physics *and* technology have increased. They indicated that because more students were exposed to technology and physics content, student interest and enrollment increased in both areas. This question of relevance to technology, therefore, seems insignificant when considering the definite and positive impact this project has had on strengthening the position of technology and vocational education in these high schools.

The outcomes have played a major role in stimulating integration that goes beyond integrated curriculum and coordinated teaching. They have set the stage to question traditional delivery systems. The project has designed models and a curriculum that will work in almost any school. Most importantly, however, is the change in relationships that occurred in the schools among the teachers. Without exception, feedback from teachers documents strong perceptual changes. Technology/vocational teachers were seen more as academic contributors as the project progressed. It seems, then, that this project has provided direction which strengthens the interrelationship between technology and vocational education with its mathematics and physics counterparts.

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