A Comparison of Second-Year Principles of Technology and High School Physics Student Achievement Using a Principles of Technology Achievement Test

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Many American companies are now faced with the toughest choices that they will ever have to make. They can continue to surrender entire industries to foreign competition, or make a philosophical break from the past by rethinking and restructuring the way they do business. While a few U.S. companies have made the break from the past, innovative companies like Xerox, Proctor and Gamble, Tektronix, General Mills, and Federal Express have implemented new strategies which emphasize continuous improvement, rapid response to market needs, self-directed work teams, and in-plant employee training and development programs (Orsburn, Moran, Musselwhite & Zenger, 1990).

American companies are seeing a continual blurring of job tasks and assignments which is resulting in a need for more functionally cross-trained employees that can blend both academic and vocational/technical skills with new skills. Companies want employees to possess skills not only in technical areas, administration, and communications (both oral and written), but also group problem solving and statistics.

According to Workforce 2000 and the National Commission on the Skills of the American Workforce, until very recently no society has needed more than 25 percent of its labor pool to possess formalized information handling skills. But, by the year 2000, 75 percent of all U.S. jobs will require not only the three “R's”, but also the four “C's”: communications, computation and computer competency (Edwards & Snyder, 1992).

Today, high school and college graduates are exposed to the basic skills (i.e. three “R's” and four “C's”). However, employers indicate that many graduates do have problems with work tasks (Edwards, 1992). While work tasks are often clear-cut applications of students' basic learning, they are often quite complex, densely detailed, and job-specific. The process of how to provide real-world application oriented training in the basic skills has been a well documented research problem since the 1930's, but only recently has it been the focus of federal legislation.

The 1990 Carl D. Perkins Vocational and Applied Technology Act provided $1.6 billion in federal funding to improve vocational programs. The Perkins Act hopes to accomplish this by making vocational funding contingent upon the integration of academics into vocational programs. These programs must be able to prepare our current and future workforce with the skills needed to function in a technologically advanced society. Some vocational education programs are attempting to meet the Perkins guidelines by emphasizing academic concepts in their existing programs.

The academic areas of science and mathematics are being integrated into the vocational curriculum not only to meet Carl Perkins requirements, but as a means of providing students with an increased level of computational and computer experiences. Physics and mathematics principles are currently the primary content for two model programs which stress interdisciplinary content areas and their connections to technology. These two programs are Phys-Ma-

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Tech and Principles of Technology. Both programs offer content examples which draw heavily from the academic subject areas of math and physics. Traditionally many vocational/technical programs have components in electricity/electronics, fluid power systems, mechanical systems and occasionally thermal energy systems. These components have been delivered in physics classes, Principles of Technology classes, as well as within traditional vocational/technical education programs. What has been lacking in at least two of these delivery vehicles is the development of an integrated system of principles that allows students to relate similar concepts and utilize transferability of the science and math content being taught (Songer & Linn, 1991).

This process of organizing information into broader categories and into more widely applicable ideas results in knowledge integration. According to Songer and Linn (1991), students develop integrated understanding by:

1. Applying pragmatic principles (conceptual) or abstract principles that summarize experiments and;
2. Analyzing prototypes (laboratory exercises) that familiarize situations that illustrate a class of scientific events.

Currently vocational/technical educators have at least three possible methods to integrate physics concepts into the vocational/technical program. These three options include: 1) adding physics content to existing vocational/technical courses; 2) requiring vocational/technical students to take existing physics courses; and 3) creating a new applications oriented physics course, or developing a course that will give students a foundation for continued learning about technology using a delivery system that focuses on lab experiences to reinforce the course content (Principles of Technology, 1985a). Vocational/technical educators choosing option three often use the Principles of Technology Program.

Principles of Technology utilizes an interdisciplinary approach that combines technology, applied physics, and applied mathematics. Upon examining the organizational matrix of Principles of Technology (see Figure 1) one can see the unifying principles that serve as unit organizers in the curriculum (Principles of Technology Curriculum, 1985b). The interdisciplinary nature of Principles of Technology provides a model for both academic and vocational/technical courses.

First Year Units	Second Year Units
Force	Momentum
Work	Waves and Vibrations
Rate	Energy Converters
Resistance	Transducers
Energy	Radiation
Power	Optical Systems
Force Transformation	Time Constants

Figure 1. Fourteen unified technical concepts.

Many times academic courses can be void of any connection to the "real" world, and vocational/technical courses can be lacking the kind of academic mathematics and science content characteristic of broadly applicable curricula. Involvement with the Principles of Technology indicates a commitment to an

interdisciplinary approach that emphasizes physics and mathematics (McCade, 1991).

Purpose

The intent of this study was to examine the impacts of the second year Principles of Technology model on achievement regarding basic physics concepts. This achievement was then compared to the achievement of students who were enrolled in high school physics classes during the year of record. The comparison was examined in light of the results of the first year study (Dugger & Johnson, 1992).

Methodology

A nonequivalent groups' pretest/posttest control group design was utilized with two treatment groups. The following figure depicts this design.

Principles of Technology	T_1	X_1	T_2
Physics	T_1	X_2	T_2
Control	T_1		T_2

T_1 = Pre-
T_2 = Post-
X_1 = PT Treatment
X_2 = Physics Treatment

Figure 2. Research Design Model.

Population and Sample

The population for this study was all secondary vocational programs in Iowa where Principles of Technology was offered. With more than 50 sites of implementation, Iowa was a good location for the study. The sites were at various stages of implementation. Sixteen sites had offered the program for two years or more. In order to obtain a better estimate of the effectiveness of the program, only sites that had offered the program for at least three years were utilized. The sample included five Iowa sites.

Of these sites, four programs were being taught by industrial technology education teachers who had participated in one two-week workshop to prepare for teaching the second year of Principles of Technology. The remaining site was taught by a certified Iowa high school physics teacher. During the data collection two programs taught by industrial technology education teachers failed to complete the study because student attrition did not allow the administration of the posttest. Therefore, the sample for this study consisted of three Iowa high schools where Principles of Technology and physics were taught as a part of the regular curriculum.

Instrument Development

As with the first year study, an item bank was generated by instructors that attended Principles of Technology workshops which provided an orientation to second year Principles of Technology units. This item bank was used as the source for the unit tests. The unit tests were then administered to each of the second year sites and scored and analyzed.

An item analysis of the unit tests enabled the researchers to identify the best questions based on difficulty, readability, and discrimination index ratings. These questions were then formed into a second year achievement instrument which included 120 items and covered each of the year-two PT objectives. Kuder-Richardson Formula 20 reliability estimates for both the unit and second year tests exceeded .90.

This test was then examined by six physics teachers to assure that all terminology and content was consistent with physics content as taught in Iowa high schools. Even though the content was consistent, certain Principles of Technology terms were found to differ from terms taught in physics classes. When this occurred, both Principles of Technology and physics terms were included for that test item.

Data Collection and Analysis

The data were collected from three sites in Iowa where second year Principles of Technology and high school physics were being taught. Phase I of the data collection involved administering the 120 item test at the beginning of the school year to 75 physics students, 24 Principles of Technology students, and a control group that consisted of 61 students who were similar to those enrolled in the principles of technology class. In all cases, the control group was an industrial technology education class with no students enrolled in PT.

The second phase of data collection consisted of posttesting which was completed approximately two weeks prior to the end of the school year. Example questions from the posttest can be found in Figure 3.

When a hydraulic cylinder is activated for 4 seconds, the piston applies a force of 70 newtons to the rod during that time period. The change in linear momentum of the fluid moved is:

a. 17.5 N·sec
b. 28 kg·m/sec
c. 175 kg·m/sec
d. 280 kg·m/sec

An angular impulse of 15 (N·m) sec is given to an object. What is the change in angular momentum of the object?

a. 0.15 kg·m^2/sec
b. 15 kg·m^2/sec
c. 150 kg·m^2/sec
d. 15 (N·m) sec^2

Figure 3. Sample questions from posttest.

A 160 lb. man dives horizontally from a 640 lb. boat with a speed of 6 ft/sec. What is the recoil velocity of the boat? The man and the boat were initially at rest.

a. 0.15 ft/sec in the same direction as the diver
b. 15 ft/sec in the opposite direction to the diver
c. 150 ft/sec in the same direction as the diver
d. 1.5 ft./sec in the opposite direction to the diver

When an empty gas bottle (initially at atmospheric pressure) is filled with carbon dioxide, a maximum *gage pressure* of 250 PSI is eventually reached. The process is described by the following equation for absolute pressure:
$P = 14.7 + 250 \text{ PSI } (1 - e^{-t/1 \text{ min}})$.

Nearly 63% of the change from 14.7 PSIG to 250 PSIG occurs in the time of _____.

a. 1 min.
b. 5 min.
c. 1.63 min.
d. none of the above

Figure 3 (continued). Sample questions from posttest.

Results

The means for both pretests and posttests are reported in Table 1. Students

Table 1
Means, Standard Deviation, and T-scores by Group for Pretests and Posttests

	Pretest		Posttest		
	Mean (SD)	N	Mean (SD)	N	T-score
PT	43.66 (8.33)	24	67.71 (12.34)	21	7.76*
Physics	43.06 (8.88)	75	51.60 (9.69)	40	4.74*
Control	34.26 (5.96)	61	37.03 (8.49)	38	1.72

*$p<.01$

who had completed year-one Principles of Technology had some background and were able to score higher than the control group (43.66 to 34.26). The mean score for students enrolled in physics was similar to that of students who had completed year-one of Principles of Technology (43.06 to 43.66). The raw score mean for the control group was significantly lower than the mean of the Principles of Technology and physics groups.

Further analysis of the means indicated that there was no significant difference between the control group pretest mean (34.26) and the control group posttest mean (37.03). This was expected since control groups by definition are not exposed to content delivered to treatment groups.

The posttest mean for the physics group (51.60) were significantly higher than the pretest mean (43.06) for the same group. Similarly, the posttest mean (67.71) was significantly higher than the corresponding pretest mean for the Principles of Technology group. There was a substantial raw score mean difference (16.11) between the Principles of Technology posttest mean and the physics group posttest mean.

A one-way analysis of variance (ANOVA) was conducted to determine if significant differences existed between three pretest groups and the three posttest groups. Table 2 addresses the pretest groups.

Table 2
Pretest ANOVA Table

Source of variation	SS	df	MS	F
Between treatments pretest	3026.85	2	1513.42	24.85*
Error	9562.46	157	60.91	
Total	12589.31	159		

*$p<.01$

There were significant differences between the Principles of Technology, physics, and control group pretest scores. Table 3 provides an analysis of the one-way ANOVA procedure for posttest means. An LSD procedure indicated that there was a significant difference between the posttest means for both the control (37.03) and physics (51.60) as well as the physics and Principles of Technology (67.71).

Exposure to traditional physics does produce significant achievement gains on a second-year Principles of Technology achievement instrument. Even greater significant gains occur if these students are exposed to a second year Principles of Technology course.

Table 3
Posttest ANOVA Table

Source of variation	SS	df	MS	F
Between treatments posttest	13051.94	2	6527.97	133.66*
Error	9374.72	96	97.65	
Total	22426.66	98		

*$p<.01$

Discussion

The results for second year Principles of Technology were similar to those determined by Dugger and Johnson (1992) for year one Principles of Technology. Students enrolled in second year Principles of Technology demonstrated a higher level of initial achievement regarding second-year Principles of Technology content. The control group provided a mean score that was closer to that of random chance on a 120 item pretest.

The posttest results indicated that the control group failed to show any gain while both the physics and Principles of Technology students demonstrated a significant increase in achievement levels regarding Principles of Technology content. The raw score mean for Principles of Technology, however, was more than 16 raw score points higher that the physics posttest mean.

Before discussion continues, two critical questions must be answered. They are; Whether Principles of Technology covers basic physics content and if so, is this content also consistent with the content taught in high school physics classes? The titles of the units covered in the Principles of Technology which consist of force, work, rate, etc. and the titles of the systems which include mechanical, electrical, fluid, and thermal certainly provide a strong *prima facie* case for consistency of content. In addition, six physics teachers have confirmed that the Principles of Technology content is consistent with the portion of the high school physics curriculum in Iowa that covers basic concepts. One may

conclude that Principles of Technology does cover basic physics content and that high school physics covers both basic and advanced physics content.

It is the belief of the authors that Principles of Technology provides a more detailed treatment of basic physics content than a typical high school physics class. The taxonomy (units and systems) of concepts and provision for application of each point result in greater achievement regarding these basic concepts. This belief is supported by Songer and Linn (1991) who indicated that students developed a better integrated understanding if pragmatic principles are applied and laboratory exercises analyzed. Considering the three possible methods for integrating physics concepts into the curriculum, the third alternative of creating a new applications oriented physics course is certainly a viable alternative based on the results of this study. One needs to be cautious, however, when discussing the relationship of Principles of Technology to high school physics classes. Even though Principles of Technology content is subsumed by the content taught in these classes, physics is asked to do much more.

Future research might investigate whether the repetition of concepts through each of the four systems (mechanical, thermal, electrical, and fluid) enhances learning or the formal theory presentations followed immediately by applications oriented laboratory experiences. Both the repetition afforded by the four systems and the applications based pedagogical approach are present in Principles of Technology. Future researchers should also consider replacing or combining the 120 item PT test with a standardized high school physics achievement test. These appear to be promising areas for future research and may yield answers that have implications for a wide range of content areas or disciplines.

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