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A Study of the Relative Achievement of Students Enrolled in Senior High School Physical Science Courses

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A STUDY OF THE RELATIVE ACHIEVEMENT OF STUDENTS ENROLLED IN SENIOR HIGH SCHOOL PHYSICAL SCIENCE COURSES

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INTRODUCTION AND STATEMENT OF PROBLEM

I. INTRODUCTION

Progress in any field demands continual self-evaluation and study. The education profession is one in which there is a constant struggle to find new, more effective methods of instruction. Thus, it is not surprising that within the area of the physical sciences, revised programs have emerged, designed to improve the scientific background and understanding of our young people.

This self-appraisal in science education has been given impetus by the large number of students enrolled in the sciences and by the importance being placed upon science at the present time. In 1957, according to a report published by the United States Government (29:18), over 98 per cent of that year's high school graduates had at least one year of science and over 75 per cent had at least two years of science. Almost one-fourth of the graduates had completed three-four years of science, and 14.2 per cent had finished four years of science courses. In another study (5:16), of over four thousand schools sampled in 1958, more than two-thirds reported an increased emphasis on science over the past three years.

The most common science subjects in the high school today are general science, biology, chemistry and physics.[1] Chemistry and physics are traditionally thought of as courses for the college-bound student (12:40, 55, 57, 73). There has been a recent trend toward development of a terminal course in physical science for high school upperclassmen who do not plan to go on to college (18:11-12; 40:60; 12:73; 25:81, 84). Much of the influence for this trend possibly could be granted to the Harvard Committee, which reported:

> But for those especially for whom secondary education is terminal, and possibly for all students, a course in a particular science does not really fulfill the aims of general education. There is a place for a rigorous and highly integrated introduction to science as a whole (16:158).

These senior-level physical science courses, which carry a wide variety of titles, normally draw their subject matter from the areas of physics, chemistry, geology, astronomy and meteorology (12:74; 3:Ch. 16). One type of course which departs from the usual physical science courses is that of earth science (40:59-60), which may include

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[1]Specific enrollments and offerings are given in these references: (5;12). For the reader who may wish a review of the subject matter commonly taught in the area of high school physical science, the following references are cited: (12:Ch. IV, V, VI; 25:80-81; 40:43-69; 30: Ch. XIII; 3:Ch. 13, 14, 16; 36:102-137).

material from geology, geography, meteorology, astronomy, oceanography and conservation (12:81).

II. STATEMENT OF THE PROBLEM

In the previous section it was noted that chemistry and physics are apparently designed for those who plan to attend college and that physical and earth science courses are planned for those who do not. Definitive studies are not readily available which illustrate that students of chemistry or physics show greater knowledge of physical science concepts than students selecting physical and/or earth science courses of general nature, or, indeed, than students who have taken <u>no</u> physical science in high school. Therefore, the purpose of this study is to analyze the relative achievement in understanding of physical science concepts among senior high school students who have taken courses in chemistry, physics and earth science. This thesis will test the hypothesis that there is no difference between students who have completed physics, chemistry, physics and chemistry, earth science, or no science in terms of their knowledge of science facts as measured by the Central Washington State College physical science exemption examination.

CHAPTER II

REVIEW OF THE LITERATURE

There is a lack of literature dealing with the relative achievement in the physical sciences between high school students who have studied different physical science subjects. By checking those indices normally available to researchers and preparing a list of references which appeared to relate to the problem, about two hundred sources were noted. A review of each reference showed that the majority were related to the problem in a most general manner and that only a few were of genuine assistance. None truly paralleled the work of this study.

Many investigations have been conducted to determine the effect of a given high school science course on the future success in that subject on the college level. Such studies give an indirect evaluation of the success of the high school course. Representative of the many reports illustrating that high school chemistry is of definite aid to the beginning college chemistry student are those by Brasted (4:562-65), Buehler (6:510-13), Carlin (7:25-26), Clark (8:133-34; 9:285-89), Foster (11:743-46), Garard and Gates (13:514-17), Glasoe (14:571-74), Hadley, Scott, and Van Lente (15:311-13), Herrmann (19:1376-85), Hill (20:323-24), Hunt (21:197-207), McQuary, Williams, and Willard (27:460-64), Meyer (28:410-14), Rogers (33:334-36), Steiner (37:530-37), Thomson (39:353-55), Wakeham (42:739-40), West (44:911-13), and Williams and Lafferty (45:207-17). Wakeham, in an earlier study (41:206-08) found that a background in high school chemistry did not result in significantly better work in college chemistry, although a combination of high school chemistry and physics was an advantage. In his later report, however, he concluded that a high school chemistry background was of advantage on the college level.

In evaluations of the effect of physics on college chemistry, Foster (11:743-46) showed that high school physics had little effect on success in college chemistry. Hadley, Scott, and Van Lente (15:311-13) found that students with a combination of mathematics, physics and chemistry in high school made the best records in college chemistry. Wakeham's second study (42:739-40) pointed out that students with high school physics who took college chemistry did almost as well as those who had high school chemistry and did better than those without high school physics. However, students with both high school chemistry and physics scored the highest of all categories and those students without either scored the lowest. Brasted (4:562-65) illustrated that students with high school physics did not do as well as did those with chemistry. Carlin's research (7:25-26) concluded that high school physics contributed little to success in college chemistry, but that a combination of physics and chemistry was superior to chemistry alone. The overall effect of the above studies, then, was to point out that a combination of chemistry and physics results in relatively higher performance in college chemistry, and a background in high school physics alone has questionable value in the study of college chemistry.

Several studies have also been completed to determine the effect of a high school physics background in the study of college physics. Results of these researches are far from uniform. Clark (9:285-89), Easter (10:729-30), Hunt (21:197-207), Hurd (22:468-70), Kruglak (24:219-22), Rogers (33:334-36), and Rudy (35:210-12) showed that students who had credit in high school physics did better in college physics than students without such previous credit, but in several instances the differences were not marked and the authors were hesitant to draw definite conclusions. Adams (1:249-50; 2:545-49) concluded his report by noting that there was little or no difference in achievement in a college physics course by those who had taken high school physics. Wise (47:418-24) found that a student who had taken both general science at the ninth grade level and physics at the senior high school level would not add materially to his understanding of physical science by taking a survey course at the junior college level. Hurd

(23:439-49) says, "There is no real evidence that high school physics is essential to successful work in college physics," and Powers (32:419-23) notes that:

> It has been shown, to be sure, that college students with credit in high school physics do somewhat better in their first college course in physics. Similar results have been found in studies of achievement in college chemistry. But these seeming advantages are small.

Thus, it is evident that contradiction exists as to the relative value of the physics course to future training in the science.

Some studies are available which compare the relative progress by students in a "fused" physical science course with the achievement of students in conventional chemistry and physics classes. A description of one such physical science course is prefaced with the comment that those taking the one-year course get a broader concept of physical science than those who take a one year course of either chemistry or physics, although no substantiating evidence is presented (38:477). Rosenlof and Wise (34:346-56), who experimented with a fused course of physical science, came to the conclusion that, per unit of time spent in the classroom, the integrated course was as efficient in teaching scientific facts as chemistry or physics.

Heidel (17:88-89) carried out an investigation comparing the outcomes of a conventional high school physics class and a general senior science course. His findings showed that while both classes were effective, the gains in the physics class were higher. The senior science class did not bring about the same gains in knowledge of specific physics materials as did the physics class. Neither class showed significant changes in scientific attitudes. The senior science class was no less effective in learning general scientific facts, principles, and applications, and the senior science class was no more effective in bringing about specific consumer outcomes or objectives. To provide valid bases of comparison, analysis of variance and co-variance were used.

Peterson (31:255-64) noted the lack of studies in this area, stating, "Little or no attention has been given to comparing the physical science survey courses at the secondary level with the conventional physics and chemistry courses." He went on to note:

> Leaders in science education and exponents of survey courses in the physical sciences have been pointing out for some time that there is a need for more studies which would evaluate the results of various courses of study. Except for Heidel's careful but rather limited study and the Rosenlof and Wise report whose findings are not convincing, there have been until this report no published accounts of studies in which the various senior high school science courses had been evaluated.

Peterson approached the problem by preparing a one-year course which integrated chemistry and physics, prepared a test by which achievement in various high school physical science courses could be compared, and evaluated his course with conventional chemistry, physics, and senior science courses. The final test contained 155 items of general chemistry and physics nature. There were no direct questions in the area of astronomy, geology, or meteorology.

During the early part of Peterson's study, the fused course, chemistry and physics were all taught in the same school by essentially the same personnel. Peterson presented an analysis of the results of this program with the conclusion that there was no significant difference between the achievement of the fusion group, the chemistry class, or the groups that had taken both chemistry and physics. There was, however, a significant difference in favor of the fusion group when compared with the physics class. A total of ninety-five students were included in this preliminary analysis.

In Peterson's main study, however, information from about one thousand cases was available. Control classes in physics, chemistry, senior science and consumer science came primarily from high schools in the east and middle west, while the fusion classes were mainly taught by Peterson from 1937-1942 in the University of Minnesota High School. At the end of the experiment, the highest-scoring group was the fusion class, followed by the students who had both chemistry and physics. The raw means of all groups were: fusion, 48.08; chemistry and physics, 35.29; chemistry, 27.15; physics, 25.02, and senior science, 22.85. Peterson summarized the results of his study as follows:

> Under controlled conditions in which intelligence quotient and chronological age were statistically equated, the physical science mean scores of students who had had one year of the Fusion of Physics and Chemistry were significantly higher than that of students who had had either 1. one year of traditional Physics, 2. one year of traditional Chemistry, 3. one year of Senior science, or 4. one year of traditional Physics plus one year of traditional Chemistry.

A final study to be mentioned in this review is one conducted recently by Lerner (26:37-38) which compared a two-year fusion course of physics and chemistry with a separate two-year sequence of traditional chemistry and physics. With forty-nine students in the experimental group and fifty-one in the control group, he found that the experimental group did slightly better on standardized chemistry and physics tests at the end of the two-year sequence, but refrained from making any conclusions other than to note that the fusion course students at least seemed to have done no worse than those in the traditional courses.

While the preceding summaries for the most part cannot be applied directly to the study under progress, they serve as useful background information inasmuch as they illustrate the nature of the research which has been carried out in the general problem area.

CHAPTER III

THE EXPERIMENT AND LIMITATIONS

In this chapter will be described the experimental procedures utilized to obtain the data which are analyzed in the following chapter. The overall design of the experiment, the test, and the sample groups will be examined in detail.

I. DESIGN OF THE STUDY

The criterion variable in this study is the score obtained on a test of specific physical science facts. The test was administered during the last month of the high school year 1964-65 to junior and senior students at four high schools in the Yakima Valley. The students had completed various physical science courses, including chemistry, physics, both chemistry and physics, and earth science. A control group which had taken no physical science in senior high school was also tested.

The nature of the study made it necessary that the test be administered at or near the end of the school year and because many school systems were unable to interrupt their already-crowded schedules, only one-half of the schools contacted were able to be of assistance. Those schools that did participate showed considerable interest in the study and gave unqualified assistance in making their facilities and student records available.

As a control variable, the prior high school grade point average (GPA) of each student was selected as being a factor representative of intelligence, previous achievement, and intangibles such as home environment and attitude.

II. THE TEST

The choice of a test was one of the most difficult portions of the overall study. The test had to be one which measured with fairness relative achievement from all of the fields under consideration and yet gave due attention to those principles thought to be essential for students in the physical sciences.

In 1943, Wise (46:67-76) selected 264 principles of physical science and ranked them in order of importance. The top one hundred concepts are listed in the report, and the findings stated:

> The upper 25 per cent of the principles includes 55 of those classified as belonging in the field of physics, 8 from the field of chemistry, and 3 from the field of geology. These figures become somewhat more meaningful when expressed in terms of percentages of the total number of principles from each specialized area. Thus, approximately 60 per cent of the 181 principles of physics, exactly 40 per cent of the 70 principles of chemistry, and approximately 29 per cent of the 21 principles of geology received relative values equal to or greater than the median value for all principles.

While a similar study today would probably not result in the same percentages, Wise's study might serve as a general guide in the selection of an effective testing instrument.

A test recently given to entering freshmen at Central Washington State College as a means for determining exemption from the general education physical science course requirement was chosen as the testing device to be used. The exemption examination consisted of eighty multiple choice questions, each of which had five responses. According to this researcher's analysis, thirty-five of the questions, or approximately 44 per cent, belonged to the general field of physics. Forty-one questions, or approximately 51 per cent, were from the field of chemistry, and four questions, 5 per cent, were from the field of astronomy. There were no questions specifically from the fields of geology, meteorology, geography or oceanography. It is stressed that this analysis might be altered slightly by others. For example, the gas laws and nuclear energy are studied in both chemistry and physics in many schools, and the interpretations as to which subject the questions belong could be varied.

It is conceivable that about 95 per cent of the material on the test could have been covered by a student who had taken both high school chemistry and physics. A student in chemistry could have completed about 65 per cent of the test material; a physics student might have encountered 55 per cent of the material, and a student in earth science would probably have been taught no more than 30 per cent of the test material.

These figures roughly match the percentages given by Wise in his analysis of the most important concepts, but it must be made clear that there is no indication that the questions on the exemption test cover those concepts found to be important by Wise. Also, it is important to keep in mind as the statistics are analyzed in the next chapter that the student who had studied both chemistry and physics might score higher on the test because he had covered the most test material, and others who had not completed chemistry and physics might have less chance of scoring well.

The test, which was machine-scored, was administered to the majority of the students by the researcher. The testing period was fifty minutes. Students were allowed to use scratch paper and slide rules, although almost no mathematical computations were required. Access to other materials such as the periodic table of the elements was not allowed. Careful control was maintained to eliminate any possibility of cheating. Students were thoroughly briefed at the beginning of the test period to allay any fears that the results of the test could have direct effects on their grades or school records. This reassurance was meant to remove any tension caused by the testing, and at the same time to encourage the students to do as well as possible.

III. THE SAMPLE

A total of 160 students in the five categories were tested but for various reasons sixteen of these scores were not used, resulting in a final total of 144 participating students, distributed as shown in Table I.

It was difficult to obtain even 21 students who had only physics (it seems that most students who take physics have had chemistry). The researcher was fortunate to find one large senior high school which had a junior physics program and which was able to provide a number of students for testing.

Since the students came from different schools, it was inevitable that they would follow different courses of study. To help the reader gain an insight into the previous background of each category of students, the basic outlines of study for the students in each group are given in the appendices. Of the students who had studied chemistry (Appendix A), approximately 29 per cent followed the first course of study, approximately 52.5 per cent followed the second course of study, and approximately 18.5 per cent followed the third course of study. Of those who had

TABLE I

DISTRIBUTION BY SEX AND YEAR IN SCHOOL OF STUDENTS PARTICIPATING IN THE STUDY

Course	Male Juniors	Female Juniors	Male Seniors	Female Seniors	Total
Chemistry	17	5	7	6	35
Physics	12	2	7	0	21
Chemistry-Physics	2	0	18	6	26
Earth Science	11	3	12	5	31
Control	2	3	8	18	31
Totals	44	13	52	35	144

studied physics (Appendix B), about 65 per cent followed the first course of study and approximately 35 per cent followed the second. Of those students studying earth science (Appendix C), approximately 39 per cent followed the first course of study and approximately 61 per cent followed the second.

In the second earth science course it is appropriate to point out that the majority of the work pertained to the earth sciences, but the latter part of the course included brief units on some of the conventional physical science topics.

All students were tested at the completion of the year's work in their respective subject. Those who had taken both chemistry and physics were tested at the end of the last of the two courses they had taken.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

This chapter contains a statistical analysis of the data obtained. Tests of significance are made between the means of all juniors and all seniors and between the means of all males and all females. The significance between means of the subgroups is tested by analysis of covariance. The significance of variances between all possible pairs of subgroups is determined, and the significance between means of all possible pairs of subgroups is found by using pooled variance.

I. PRELIMINARY RESULTS

A summary of the experimental data is presented in Table II. Based upon total correct responses out of eighty items, those students who had completed both chemistry and physics had the highest average, 55.15, and those students who had not completed any physical science course had the lowest average, 24.97. The mean for the five groups was 39.74.

An analysis was made of the scores of the high school students in this study with respect to standards for exemption from the physical science course at Central Washington State College. Students exempted from the general education physical science course at Central

TABLE II

SUMMARY OF EXPERIMENTAL DATA

PART A: TEST SCORES (EIGHTY ITEMS)

Category	Range	ΣY	$\bar{Y}$	ΣY^2
Chemistry	35-62	1700	48.57	84,062
Physics	30-68	968	46.10	45,966
Chemistry-Physics	36-66	1434	55.15	80,650
Earth Science	16-40	847	27.32	24,331
Control	14-37	774	24.97	20,356
Total	---	5723	39.74	255,365

PART B: HIGH SCHOOL GRADE POINT AVERAGES AND CROSSPRODUCTS

Category	ΣX	$\bar{X}$	ΣX^2	ΣXY
Chemistry	110.33	3.15	357.4363	5399.11
Physics	66.10	3.15	213.5766	3102.25
Chemistry-Physics	80.20	3.08	257.7382	4467.16
Earth Science	60.66	1.95	121.9002	1668.27
Control	73.11	2.36	184.4917	1907.17
Total	390.40	2.71	1135.1430	16,543.96

Washington State College had to attain a score of forty if they had not had high school physics or chemistry, and a score of thirty-two if they had. All of the high school students in this study who had chemistry or both chemistry and physics, and all but one of the physics students, attained the exemption standard set by the college. Almost all of the students in the earth science group and all of the students in the control group failed to meet the standards. Table III shows the percentage of each group meeting the exemption standard.

A separate group analysis of the significance between the mean scores on the criterion variable of juniors in all categories and of seniors in all categories was made (43: 129-33). The mean for the juniors was 42.21 and for the seniors was 38.13. The value of t was 1.79, which is not significant at the 5 per cent level of confidence.

The second analysis of difference between means was made with respect to all males and all females, regardless of category. The mean for the males was 42.03 and the mean for the females was 35.17. The value obtained for t was 2.87, which is significant at the 1 per cent level of confidence.

A test was applied to the means of all males and all females exclusive of the control group. The males had a mean of 43.89 and the females had a mean of 41.89. The

TABLE III

NUMBER OF STUDENTS IN THE STUDY WHO MET EXEMPTION REQUIREMENT OF CENTRAL WASHINGTON STATE COLLEGE PHYSICAL SCIENCE EXAMINATION

Category	Number of Students	Number Meeting Exemption Requirement*	Percentage
Chemistry	35	35	100
Physics	21	20	95
Chemistry-Physics	36	36	100
Earth Science	31	2	6.5
Control	31	0	0
Total	144	93	64.5

*Thirty-two out of eighty correct responses required for those with chemistry or physics background. Forty out of eighty correct responses required for those with no chemistry or physics background.

t-value was 0.664, which was not significant at the 5 per cent level of confidence.

Another test was made comparing the means of the males and females in the control group. The females had a mean of 26.52 and the males had a mean of 21.70. The value of t, 2.80, was significant at the 5 per cent level of confidence.

A summary of the findings in this section is shown in Table IV.

II. DIFFERENCES BETWEEN THE MEANS OF THE FIVE GROUPS

To test if there existed a significant difference between any of the groups, an analysis of covariance (43: 343-52) was made. This procedure allows a test of significance to be made while employing control variables. The control variable used was the high school grade point average (GPA).

The value obtained for F was 57.60, which is of significance at the 1 per cent level. Insofar as the GPA provides a valid control factor, and within the limitations of the experiment, a significant difference between the means of the students in the five groups was thus demonstrated.

Adjusted criterion means were computed for the five groups. The adjusted means for each group are shown in

TABLE IV

RESULTS OF TESTS OF SIGNIFICANCE BETWEEN MEANS OF JUNIORS AND SENIORS AND BETWEEN MALES AND FEMALES

Groups Compared	Number	Mean	Difference Between Means	Value of t	Significance
All Juniors in all Categories	57	42.21			
All Seniors in all Categories	87	38.13	4.08	1.79	None at 5% level
All Males in all Categories	96	42.03			
All Females in all Categories	48	35.17	6.86	2.87	Significant at 1% level
All Males Excluding Control Group	87	43.89			
All Females Excluding Control Group	27	41.89	2.00	0.664	None at 5% level
All Males in Control Group	10	21.70			
All Females in Control Group	21	26.52	4.82	2.80	Significant at 5% level

Table V.

III. DIFFERENCES IN VARIANCES BETWEEN PAIRED GROUPS

Tests were made to determine if there were significant differences in the variances between pairs of groups so that the appropriate test for significance of difference between means could be applied (43:133-35).

Significance at the 10 per cent level of confidence was found in the comparison between the physics and control groups. In all other pairs of groups, there was no significance between the variances. A summary of the analysis is shown in Table VI.

IV. SIGNIFICANCE OF MEANS BETWEEN PAIRED GROUPS

The difference between the means of each pair of groups was tested for significance by pooled variance (43: 135-37).

A comparison was made between each possible pair of groups. There was no significant difference between the means of the chemistry and physics groups, nor between the means of the earth science and control groups. All other pairings showed significance at the 1 per cent level of significance. A summary of the results of the pooled variance test is shown in Table VII.

TABLE V

ADJUSTMENT OF MEANS FOR THE FIVE GROUPS

Category	Mean	Adjustment Term	Adjusted Mean
Chemistry	48.57	2.50	46.07
Physics	46.10	2.50	43.60
Chemistry-Physics	55.15	2.11	53.04
Earth Science	27.32	-4.32	31.64
Control	24.97	-1.99	26.96

TABLE VI

VALUES OF F FOR VARIANCES BETWEEN GROUPS

	Chemistry	Physics	Chemistry-Physics	Earth Science	Control
Chemistry	---	1.53	1.42	1.11	1.28
Physics	1.53	---	1.08	1.70	1.96*
Chemistry-Physics	1.42	1.08	---	1.57	1.81
Earth Science	1.11	1.70	1.57	---	1.15
Control	1.28	1.96*	1.81	1.15	---

*Significance at 10 per cent level.

TABLE VII

VALUES OF t FOR PAIRED GROUPS USING POOLED VARIANCE

	Chemistry	Physics	Chemistry-Physics	Earth Science	Control
Chemistry	---	1.23	3.54*	13.32*	15.24*
Physics	1.23	---	3.84*	9.33*	10.84**
Chemistry-Physics	3.54*	3.84*	---	14.80*	16.54*
Earth Science	13.32*	9.33*	14.80*	---	1.52
Control	15.24*	10.84**	16.54*	1.52	---

*Significance at 1 per cent level.

**Value of t also computed for physics-control comparison, using the procedure in Section I, Chapter IV. The value of t was 10.16, demonstrating significance at the 1 per cent level.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

I. SUMMARY

This study was designed to evaluate the relative achievement of students enrolled in certain senior high school physical science courses.

A review of the literature showed that students who have credit in high school chemistry have a better chance of success in the early stages of college chemistry work. A similar trend seems to apply to high school physics students who go on to take college physics. However, the value of the high school physics course is not as marked. The students who have credit in both high school chemistry and physics tend to achieve higher in the early stages of college chemistry than the students who have had only one of the two courses.

There has been some experimentation with fusion courses of physics and chemistry. There is an indication that students who complete such fusion courses generally do as well or better than students who have spent an equivalent amount of time in traditional chemistry or physics classes.

This study was conducted during the latter part of the high school year 1964-65. A test of physical science facts, largely in the area of chemistry and physics, was administered to students at four high schools in the Yakima Valley. One hundred and forty-four usable sets of scores were obtained from thirty-five students who had just completed a year of chemistry, twenty-one students who had just completed a year of physics, twenty-six who had completed a year of chemistry and a year of physics, thirty-one students who had completed a year of senior science best described as earth science, and thirty-one students who had taken no physical science in the senior high school. All students were juniors and seniors.

The scores obtained from the tests were analyzed using several statistical procedures. On the basis of the past use of the test (that of a physical science exemption examination at Central Washington State College), virtually all of the students with chemistry, physics, or chemistry and physics backgrounds attained the exemption standards set for students entering the college. Almost all of the students with earth science or no physical science background failed to meet the exemption standards.

There was no significant difference in the mean of all juniors when compared with the mean of all seniors. When the mean of all males was compared with the mean of all females, the mean of the males was significantly higher. However, excluding the control group, there was no significant difference between the means of males and females.

An analysis of covariance, using high school GPA as a control variable, showed a very high significance in the difference between the means of the five groups.

The variances between paired groups were not significant at the 10 per cent level, except for the physics-control comparison.

A test of the significance between means of each possible pair of groups, using the technique of pooled variance, showed significance between each paired group at both the 5 per cent and 1 per cent level of confidence, with the exception of the chemistry-physics and earth science-control pairings.

II. CONCLUSIONS

Conclusions which seem warranted on the basis of the data cited are as follows:

1. Students who completed high school chemistry and physics showed a greater knowledge of factual information regarding physical science than students who had not.

2. Students who completed either high school chemistry or high school physics had a high level of knowledge of physical science but less than students who completed both sciences.

3. Students who had only earth science or no physical

science showed a low level of knowledge of physical science as compared to those students who completed either chemistry or physics, or both.

4. There was no significant difference in the knowledge of physical science facts between students who had earth science and those who did not study a physical science.

5. There was no significant difference in the knowledge of physical science facts between juniors and seniors.

6. There was no significant difference in the knowledge of physical science facts between males who completed physical science courses and females who completed physical science courses.

7. There was no significant difference in the knowledge of physical science facts between students who studied chemistry and students who studied physics.

III. RECOMMENDATIONS

Based upon the literature, the data, and the conclusions, the following recommendations are made:

1. This type of study should be repeated with larger populations and with more uniformity of the course contents for the groups being tested.

2. A testing instrument which includes more items from the other areas of physical science, such as geology, meteorology, and oceanography, should be developed specifi-

cally for the study recommended above.

3. Physical science courses for senior high school terminal students should be subjected to review and efforts made to identify those factors which may presently decrease the effectiveness of the courses.

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APPENDICES

APPENDIX A

APPENDIX A

COURSES OF STUDY IN CHEMISTRY

I. Approximately 29 per cent of the students who participated in this study and had studied chemistry followed this general course outline:

Topics:
1. Introduction to chemistry; composition of matter; matter and its changes.
2. Atomic theory and structure; Periodic Law; chemical bonds; formulas.
3. Oxygen; hydrogen; gas laws; water.
4. Equations; mass and volume relations.
5. Carbon and its compounds; hydrocarbons.
6. Ionization; crystallization; acids; bases; salts; equilibrium; redox reactions.
7. Colloidal state.
8. Basic organic chemistry.
9. Elementary qualitative techniques.

II. Approximately 52.5 per cent of the students who participated in this study and had studied chemistry followed this general course outline:

Topics:
1. Introduction to chemistry; elements; compounds; atomic structure and transformations.
2. Oxygen; hydrogen; water.
3. Periodic chart; atomic structure; electron chart; bonding.
4. Ionization; acids; bases; salts; electrochemistry.
5. Formula weights; moles; atomic weights; reactions; standard solutions.
6. Sulfur; its compounds and reactions.
7. Halogens
8. Isotopes; radioactivity; nuclear energy.
9. Nitrogen; its compounds and reactions.
10. Carbon; common compounds.
11. Organic chemistry fundamentals.
12. Metals; iron; aluminum; magnesium; copper.
13. Fibers; dyes; plastics.
14. Colloids.
15. Applied and theoretical chemistry.

III. Approximately 18.5 per cent of the students who participated in this study and had studied chemistry followed this general course outline:

Topics:
1. Introduction to chemistry; matter and properties.
2. Oxygen; hydrogen; water.
3. Atomic structure.
4. Chemical bonds; periodic table.
5. Formulas; equations.
6. Solutions; colloids; crystals.
7. Reactions.
8. Mathematics of chemistry.
9. Ionization.
10. Acids; bases; salts; equilibrium.
11. Halogens.
12. Sulfur and its compounds.
13. Atmosphere; nitrogen.
14. Carbon; silicon; boron.
15. Sodium; potassium; calcium.
16. Metals and metallurgy.
17. Iron; nickel; cobalt; platinum.
18. Copper, zinc, and tin.
19. The light metals; other important metals.
20. Organic chemistry fundamentals.
21. Applications of chemistry.
22. Nuclear reactions; atomic energy.

APPENDIX B

APPENDIX B

COURSES OF STUDY IN PHYSICS

I. Approximately 65 per cent of the students who participated in this study and had studied physics followed this general course outline:

Topics:
1. Matter; energy; measurement.
2. Force, motion; work; power; energy; machines.
3. Atomic structure; radioactivity; nuclear energy.
4. Kinetic theory of matter.
5. Heat; expansion; change of state.
6. Sound; wave motion.
7. Illumination; reflection; refraction; color.
8. Electrostatics; direct current circuits; magnetic effects.
9. Electromagnetic induction; alternating current circuits; resonance.

II. Approximately 35 per cent of the students who participated in this study and had studied physics followed this general outline, which was for a PSSC course:

1. Time; space; functions and scaling; motion; vectors.
2. Mass; elements; atoms; molecules; gases.
3. Measurement.
4. Reflection; images; refraction; optical instruments.
5. Waves; waves and light; interference.
6. Motion; universal gravitation; momentum.
7. Work; energy; heat; molecular motion.
8. Electricity; magnetic field; induction; electromagnetic waves.
9. Photons; matter waves; quantum systems; structure of atoms.

APPENDIX C

APPENDIX C

COURSES OF STUDY IN EARTH SCIENCE

I. Approximately 39 per cent of the students who participated in this study and had studied earth science followed this general course outline:

Topics:
1. The earth's surface; minerals.
2. Maps.
3. Weathering; water; wind; glaciers.
4. Earthquakes; volcanoes.
5. Land forms.
6. Conservation
7. Prehistoric times.
8. Astronomy.
9. Meteorology.
10. Oceanography.
11. Climates.

II. Approximately 61 per cent of the students who participated in this study and had studied earth science followed this general course outline:

Topics:
1. Earth and its development.
2. Earth's crust; land forms.
3. Polar and desert regions.
4. Oceanography.
5. Meteorology.
6. Astronomy.
7. Space travel.
8. Sound.
9. Simple machines.
10. Basic chemistry.
11. The atom.
12. Photography.
13. Electricity.