COMBINED SCIENCE COURSES

325
1226-5600

by

DONALD MCLEAN TROTTER, JR.

B. S., Kansas State University, 1971

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Physical Science Teaching

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Approved by:

Robert K. James
Major Professor

ACKNOWLEDGMENTS

The author gratefully acknowledges the guidance and patience of his major professor, Dr. Robert K. James, Associate Professor of Curriculum and Instruction. The assistance of Dr. J. Harvey Littrell, Professor of Curriculum and Instruction is also appreciated.

TABLE OF CONTENTS

Chapter 1

INTRODUCTION

For some time the idea of combining several traditionally-separate scholastic courses into one broader course, which cuts across discipline barriers, has been held to be desirable on theoretical grounds. Such combined courses are thought to make the learned material more functional in the life of the learner,[1] since the information which must be applied to solve life's problems seldom comes from only one of the traditional disciplines.[2] Such courses are thus thought more lifelike, and better able to contribute directly and significantly to the society they are designed to serve.[3] A lack of understanding of the interrelatedness of what is learned prevents proper comprehension of the problems of modern life,[4] and courses which do not promote such understanding are unrealistic since they are based on an organization unrelated to the use to which the learning is to be put.[5]

Easy transfer of learning from one discipline to another is a common course goal. Toward this end teachers are trained to "teach for transfer," that is, to teach in such a manner as to facilitate use of material taught in his class in another. Combined courses are reported to enhance transfer from one discipline area to another,[6] since several disciplines are included in a single course, and also because the combined nature of the course forces the student to use material from one discipline in another.

Combined courses also take into account the psychological principles of securing mass impressions and large overviews of patterns before details are discussed.[7] The most efficient means of teaching facts, and the relationships of those facts, is by presenting a broad, general framework first, then proceeding to more and more specific detail. Combining courses allows the use of much broader and more general frameworks and patterns.

In the science area, due in part to their theoretical desirability, combined courses, particularly ones combining physics and chemistry or mathematics, have been stimulating increasing interest and effort on both the secondary and college levels. In 1957 a conference sponsored by the American Association of Physics Teachers[8] recommended that freshman college physics courses should include, as part of their subject matter, ideas, such as the calculus, and topics, such as the molecular structure of matter, usually reserved for mathematics and chemistry classes. In 1958, a conference sponsored by the Committee on Teaching of the Division of Chemical Education of the American Chemical Society[9] held that since neither modern chemistry nor modern physics can be understood without a knowledge of the other science, the best and most effective way to teach these subjects, on the secondary level, is through a combined, two-year course in the two sciences. A progress report[10] of the Panel on Educational Research and Development went even further in recommending a three-year combined high school course, to include biology as well as physics and chemistry. As early as 1957, the Wyndham Conference, dealing with secondary education in Australia, recommended[11] that a four-year combined course in the sciences be required of all secondary students.

In 1961 there were 12 college-level courses, intended primarily for science majors, combining physics and chemistry or mathematics.[12] By 1964 this figure had risen to 22; and in 1966, based on a survey[13] of 900 four-year colleges and universities, and 700 two-year colleges, there were 37 such courses: 26 combining physics and chemistry, 7 combining physics, chemistry, and mathematics, and 4 combining physics and mathematics. In addition,[14] there were 45 other college courses, primarily for science majors, offering various other combinations of disciplines chosen from chemistry, biology, physics, geology, and mathematics, including one ambitious course that included them all. The same survey[15] revealed that in 1966 there were 421 institutions giving college level courses, primarily intended for non-science majors, which combined two or more sciences and/or mathematics. Of these,[16] 221 were survey-type courses, often called "Physical Science," 64% of which were one-fourth to one-half chemistry,[17] the remainder being physics, geology, and astronomy. Of the remaining 200 courses, 109 combined[18] physics and chemistry, 15 combined physics, chemistry, and mathematics, and 7 combined physics and mathematics. The rest were various other combinations of biology, chemistry, physics, mathematics, geology, and astronomy. A 1972 survey[19] showed that of 30 universities and other institutions reporting combined science courses, 21 offered their courses for all students, 6 for non-science majors, and 2 for science majors.

At the secondary level in 1972, combined science courses were reported by a survey[20] as being locally developed by 30 high schools, with 38 more high schools using courses already developed or obtained elsewhere. Another source[21] gives a list of 22 schools using combined science courses they have developed themselves.

The source other than local development of a combined science course is generally a national curriculum development project. Prominent among these are such projects as the "Portland Project," the Nebraska Physical Science Project (NPSP), and the Physical Science for Non-Science Students Project (PSNS). Several of these projects are now completed but other similar projects continue.

The Portland Project, conducted by a group at the Portland, Oregon, Curriculum Center, developed two, two-year physics-chemistry combined courses for the secondary level.[22, 23, 24] Each of these courses combined materials previously developed by national curriculum projects in a single science. One of the Portland Project courses uses the physics materials developed by the Physical Science Study Committee (PSSC), and the chemistry materials of the Chemical Education Materials Study (CHEMS). The other Portland Project course uses PSSC physics materials and Chemical Bond Approach (CBA) chemistry materials. A survey completed in 1965[25] showed that 1550 students in 40 schools throughout the country were being instructed using one of the combined courses developed by the Portland Project.

The Nebraska Physical Science Project course,[26] developed by the University of Nebraska, the Nebraska State Department of Education, and the Nebraska secondary schools, is a two-year combination of secondary-level physics and chemistry, designed to maximize individualization of instruction. In the 1970-71 school year,[27] 1,000 students in 25 schools were taught using this course.

The Physical Science for Non-Science Students course, the development of which was sponsored[28] by the Advisory Council on College Chemistry, and the Commission on College Physics, and funded by the National Science Foundation, is aimed at college students, primarily those who are not majoring in science,[29] but who are required to take a science course. Usually more than half of this group is education majors.[30] The course occupies two semesters, and is designed to replace the semester of physics and the semester of chemistry such students ordinarily take.[31] Content is approached via the study of solid matter, using both physics and chemistry principles to find out how matter got to be the way it is, how it can be changed, and how to find out about it. In the 1967-68 academic year, 38 colleges were using this course.[32]

PURPOSE OF THIS STUDY

Much interest and effort have been expended on combining physics and chemistry or mathematics in one course. The purpose of this report is to examine both the advantages and the disadvantages that have been claimed in the literature for such courses and to describe some of the characteristics of such courses.

Literature available on the campus of Kansas State University was examined. The results of that examination constitute most of the remainder of this report, which is divided into chapters on: "Advantages of Combined Courses," "Disadvantages of Combined Courses," and "Characteristics of Combined Courses."

DEFINITIONS

For purposes of this report, a combined course is defined to be any secondary or college level course including as its primary subject matter physics and chemistry, physics and mathematics, or physics, chemistry, and mathematics. This does not exclude courses including small amounts of biology, geology, or astronomy, but does exclude strictly survey-type courses. "Combined course" is intended to be a rather general term, encompassing courses variously referred to in the literature as "fused," "integrated," "multidisciplinary" and "unified," among others, and emphasizing the choice of subject matter from several disciplines as the salient aspect of such courses.

Chapter 2

ADVANTAGES OF COMBINED COURSES

ELIMINATING DUPLICATION AND REPETITION

One of the advantages of combined courses most often claimed in the literature examined was that such courses eliminate the duplication and repetition which occurs in separately-taught courses, and consequently save time, allowing shorter courses or broader coverage. As the National Science Board pointed out in 1970,[33] there is a large area common to physics and chemistry, where the difference is more in style and perspective than in subject matter, and the unity of the physical sciences involves as well the expanding use of mathematics as a common language among all fields. In 1961, a conference[34] of physicists and chemists listed the topics that physics and chemistry have in common and which are suitable for a combined course. The same conference pointed out[35] that one of the advantages of combined programs is that they save time, since topics common to both disciplines would not be taught twice. Several other authors[36, 37, 38] make the same point. Another author[39] makes the same point yet again, and asserts that this is the main reason that college physics and chemistry departments are interested in combined courses. One of the major goals of the Portland Project[40, 41] was to design a course that eliminated repetition, and this was a major goal of the Nebraska Physical Science Project as well.[42]

Although quantitative data are sparse, reports on combined courses actually in use tend to confirm that repetition and duplication are lessened, with a consequent saving in time. On the secondary level, a two-year course combining physics and chemistry is reported[43] to provide slightly greater coverage of both physics and chemistry concepts than two separate one-year courses do. In a two-year course combining physics and calculus,[44] calculus coverage was reported to run six weeks ahead of the previously-used, separate course. Physics coverage, however, ran several weeks behind, due to calculus applications being taught as part of physics. On the college level, a four-semester course in physics and chemistry is reported[45] to cover one-half semester more chemistry than previous, separately-taught courses. A six-quarter course in physics, chemistry, and biology, requiring six credits per quarter, occupies 14% fewer credit hours than three separate courses in physics, chemistry, and biology.[46]

EACH SCIENCE NEEDED FOR UNDERSTANDING OF THE OTHER

As has already been pointed out, there is a large area common to physics and chemistry, and mathematics is used in both. For this reason it frequently occurs that material traditionally covered in a class in one of these subjects is required for a proper understanding of material covered in another.[47] There is, according to Victor Showalter,[48] no basis for the once often-heard argument that physics should precede chemistry; indeed students in each area need a strong background in the other.[49] Today, more and more, mathematics is being used in physics and chemistry, at all levels, for the framing and solution of problems.[50] Thus, each science being needed for a proper understanding of the other, it is often argued that they should be taught in a combined course.

At the secondary level, physics and mathematics scarcely reach the levels of abstraction which make them separate, independent bodies of knowledge.[51] Mathematics is not developed axiomatically, but rather by comparison with how the student "knows" the real, physical world operates. Physics is developed largely as a "substitute-in-the-formula" structure, using mathematical rules the student intuitively knows are correct. Thus the two are already merged in practice[52] and might just as well be taught as one course.

PSSC physics, a course which is currently taught in many high schools, requires mathematical knowledge including ratios, exponents and radicals, graphs and graph interpretation, simple equation solving, and some geometry.[53] This is considerably less than the material covered in the first two years of secondary school mathematics,[54] and can easily be covered in a two-year combined course. Without the ability to apply mathematics to practical problems, the student will not benefit from his physics course.[55] A student who has not achieved this ability in his mathematics courses is not likely to achieve it in his physics course.[56] Questionnaire responses by students indicate that combining the two subjects makes the mathematics more meaningful, since it can be applied to the physics problems,[57] and combining the subjects assures that the student will benefit from the physics part of the course, since he will have had practice in applying the mathematics.

Such combination also eliminates the duplication which sometimes occurs when the physics teacher has taught a needed mathematical technique which is then later taught in the mathematics class.[58] Problems of different notation and definition for the same quantities in each class are also eliminated.[59]

A proper understanding of chemistry requires a perception of the framework of principles and theories underlying the subject, but modern chemical theories are increasingly physics oriented.[60] Conversely, understanding physics requires understanding chemistry.[61] Realizing this, the PSSC, which ultimately produced a high-school physics course, was originally organized to design a two-year combined physics-chemistry course.[62] Clarifying the relationship between physics and chemistry was a major goal of the Portland Project.[63] A beginning student of chemistry often must take such topics as atomic structure on faith because he has had too little physics background.[64] Combining the two subjects assures that when a concept from one subject is needed to explain a concept in another, it will be taught to the student, not left largely to the other course.

GIVES BROAD OVERVIEW OF THEORETICAL FRAMEWORK

Since an understanding of physics, chemistry, or mathematics assists in understanding the other two, it is often argued that a combined course gives both the student and the teacher a better conception of science as an interlocking set of laws and theories, rather than as a group of isolated, unrelated disciplines.[65-68] Such ideas as physical and mathematical models, and the transient nature of concepts and theories are common to all of the sciences and can be emphasized in a combined course.[69, 70] The laws of thermodynamics permeate the content of the Biological Sciences Curriculum Study course, as well as the CBA and PSSC courses,[71] and can also be emphasized in a combined course. A combined course lends itself well to a "spiral approach"[72]--the introduction of a topic at one level of complexity, then, after new, improved laws and theories are discussed, reintroducing the same topic at a higher level of complexity using the new ideas and theories. This tends to demonstrate to the student how new theories have helped in the advancement of science, and also that new theories must fit old observations.

Test results of students taking a secondary-level combined course show that those in the upper two-thirds of the IQ score range have a significant advantage over similar students in separate courses in respect to the attainment of a "rational image of the universe," while there is no difference between the two groups in the lower one-third of the IQ score range.[73, 74]

Finally, by forcing teachers in one subject to teach material in another subject, the teacher's outlook on science is broadened,[75, 76, 77] both due to his having to get out of his area of specialization and learn material in another, and by his having to think about both areas together, thus discovering relationships between them he had never noticed before.

BETTER DEPTH STUDY

Combined courses should provide the student with a deeper understanding of each discipline than separate courses would.[78] To some extent this is a consequence of the time saving, resulting from the elimination of repetition allowing the student to proceed farther into his subjects than would otherwise be possible.[79] Greater depth of study is also inherent in the combined approach. With separate courses, learning in depth will often not take place because fundamental concepts from one subject may not be introduced until long after the need for them has arisen in another subject.[80] With a combined course this is avoided. In addition, a spiral approach, which aids depth learning, is easily employed in a combined course.[81]

A report on a two-year combined physics-mathematics course at Putney School, Putney, Vermont, indicates that a more thoughtful and careful development of essential skills results from the combined approach, even though no more actual time is spent on them than in separate courses.[82] Another combined course is reported to give greater depth and breadth to studies than do separate courses.[83]

GOOD FOR EDUCATION MAJORS

It is often pointed out that combined courses are especially well-suited to the needs of college students majoring in education--particularly those planning to become secondary science teachers or elementary teachers.[84, 85, 86, 87] Such persons are often required to teach subject matter from a number of disciplines, the elementary teacher in what is broadly termed "science," and the secondary science teacher in several separate courses, as a result of there usually not being enough classes in just one discipline to justify a full-time teacher.[88] By taking a combined course, the prospective teacher gains the needed subject matter background, as well as a better overall view of the theoretical framework of science, and a deeper understanding of his subject, both of which are extremely desirable in a science teacher.

With this is mind, several curriculum development projects entirely or partially for education majors have been established. The PSNS project was set up with elementary education majors as one of its principal target groups.[89] The Physical Science Group at the Educational Development Center is working on a four-year program aimed at producing high school combined physics-chemistry teachers.[90] At Wisconsin State College, Eau Claire, a four-year program designed to train secondary physics and mathematics teachers has graduated 18 students since it was begun in 1963.[91] A 1972 survey noted three universities providing teacher training in combined science.[92] In 1967, a survey noted no universities gave combined courses for education majors.[93]

INCREASES STUDENT INTEREST

Another reason mentioned for adoption of a combined course is that students in such a course show increased interest in science, based on both subjective evaluations and enrollment figures. Students in a one-year college physics-chemistry-mathematics class show unusually great interest in calculus when it is demonstrated how calculus can be used to solve physics and chemistry problems.[94]

High school students in a one-year combined physics-chemistry class demonstrated higher interest, participation, and success, based on attitudes, grades, and requests for counseling, than did students in separate courses; and the incidence of failures and dropouts was significantly lower as well.[95]

At Villa Madonna Academy, Covington, Kentucky, a three-year course in physics, biology, chemistry, and mathematics was adopted, replacing separate courses in those subjects.[96] State law required that students take the first two years of science; the third was optional. Previously, when the third year of science consisted entirely of physics, only 15% of the senior class elected it.[97] In the 1971-72 school year, 43% of the senior class elected the third year of the combined course.[98] It should be noted, however, that the third year of the combined course is not as difficult as the physics course was.[99]

As part of the evaluation for the Portland Project combined course, five Portland, Oregon, high schools used the combined course for some of their students, while the rest were offered separate courses in physics and chemistry.[100] The number of students which started in the combined class, the number which continued in the combined class the second year, the percentage of students which continued the second year, and the percentage of students which completed both physics and chemistry in separate classes, thus covering the same amount of material as students in the combined course, was determined. The results, summarized in Table 1 on the following page, showed that in each school, a higher percentage of students took two years of the combined course than took both separate courses.[101]

Table 1

Retention of Students in Portland Project Combined Course and Separate Courses

School	No. Started Combined Class	No. Continued Second Year	% Continuing Second Year	% Completing Both Chemistry & Physics, Taught Separately
A	22	18	82%	70%*
B	24	22	92%	50%
C	21	18	86%	40%
D**	45	25	56%	39%
E	19	17	89%	40%

*Chemistry and physics are taught in the reverse order at this school

**Higher ability students were not included as part of the experimental group; consequently, a smaller number would be expected to elect the second year

After Fiasca, Michael "Evaluation of the Integrated Chemistry-Physics Course Developed by the Portland Project." Unpublished Report (Mimeographed), Portland State College, Portland Oregon, 1965. Quoted in FUSE Bulletin-No. 4, April, 1967, p. 4.

On the college level, in evaluating the PSNS course, it was found that when students were randomly assigned to either a standard "Physical Science" course, or the PSNS combined course, 29% subsequently dropped the PSNS course, compared to 37% dropping the standard course, based on a sample of 425 in the PSNS course and 575 in the standard course.[102]

At Maryville College, Maryville, Tennessee, two new combined courses were introduced in 1967 to replace traditional freshman physics, chemistry, and biology. Questionnaires administered to students who had taken the new courses showed that 77% felt that their appreciation of science had been enhanced, 82% said that they felt that the combined approach should be continued, and 66% felt that the new courses had stimulated their desire to learn more about science.[103]

STUDENT MAKES A BETTER CHOICE OF MAJOR

On the college level, combined courses have been advocated as allowing the student to make an earlier, wiser choice of major, since he is exposed to several sciences sooner than he might otherwise be.[104, 105] It often happens that the student can take chemistry-major chemistry in his freshman year, but due to the greater mathematics prerequisites, must wait until his sophomore year to take physics-major physics. This means that when the student is just beginning his study of physics, he is ready for upper-level chemistry courses, and may be predisposed to choose chemistry over physics as a major. One author[106] argues that physics departments advocate combined courses because they allow the physicist to attempt to gain converts a year earlier, and that both physics and chemistry departments advocate such courses since they allow each to proselytize among the other's students, and the uncommitted as well.

Some combined courses,[107] are designed so that the student can begin upper-level courses in his major area, irregardless of which it is, as early as his sophomore year. Having been exposed to enough of each science to make a wise choice of major, many elect to do so. Even if they do not, they have gotten started in their major field sooner than would otherwise be the case.

ALLOWS LONGER CONTINUOUS STUDY

In a number of cases, depending on details of how the class is scheduled, combined courses allow a longer period of continuous study than do separate courses. Sometimes the combined course may stretch out over several years, making it possible for the student to get two or three years continuous study of algebra without the usual year-long break for geometry.[108] In other cases,[109] where the class is allotted two contiguous periods a day, it is possible, for instance, to set up, perform, and analyze the results of an experiment in a single day. Either of these possibilities appears quite desirable.

DEVELOPS CLASS SPIRIT

As a consequence of the way they are scheduled, combined classes sometimes put the same students together in a class for two periods a day, and/or for two years in a row. This fact, plus the students' feeling that they are in a prestigious class, leads to the development of a "class spirit" which is more pronounced than in the usual class.[110] This spirit usually manifests itself in a greater amount of intra-group studying and social interaction than is present with separately-taught classes,[111] and would seem to be a desirable goal.

EVALUATIONS

In spite of the large body of opinion, cited above, that combined courses theoretically offer advantages over separately-taught courses, a question still remains as to whether or not combined courses are more effective in actual practice. That is, do students who have taken combined courses do better, in terms of test results, than students in separately-taught courses?

On the college level, information to help answer this question is provided by the evaluation program of a national curriculum development project, and by the evaluation of a locally-developed course. In the pilot-testing phase of the PSNS national project, during the 1969-70 academic year, twelve instructors in ten colleges in eight states used PSNS materials for the first time. Each instructor randomly assigned students to a conventional "physical science" course, or to a PSNS course, and the same instructor taught both courses.[112] A total of 425 students were assigned to the experimental group, taking the PSNS course, and 575 were assigned to the control group, taking the conventional course.[113] A variety of pre- and post-tests, some commercially published, and some of which were written by the PSNS staff, were given at various times throughout the year to both the experimental and control groups. The experimental group scored significantly higher on the Test on Understanding Science and the Science Process Inventory. There was no significant difference between the two groups on the Academic Interest Measure of Physical Science, or on a science attitude inventory written by the PSNS staff.[114]

A locally-developed combined course provides another indication of the comparative effectiveness of such courses at the college level. Students in a combined physics-chemistry curriculum, involving combined physics-chemistry courses in both the freshman and junior years, at Claremont Men's College, Pitzer College, Scripp's College, Harvey Mudd College, and Pomona College, all in Claremont, California, took the ACS Cooperative General Chemistry Test, Form 1963. Results showed that these students compared favorably with the national norms for this standardized test, even though they had had less than the usual amount of qualitative analysis laboratory.[115]

On the secondary level, evaluation information was found for a national curriculum development project course, and for a number of locally-developed courses.

As part of the pilot study of the Portland Project, in the 1963-64 academic year, five Portland, Oregon, schools taught both separate courses in CBA chemistry, CHEMS chemistry, and PSSC physics as well as combined courses in CBA Chemistry-PSSC Physics, and CHEMS Chemistry-PSSC Physics. Six experimental classes were given instruction in one of the combined courses, and each class was compared, using a pre- and a post-test with six PSSC control classes, three CBA control classes, and three CHEMS control classes.[116] The tests were composed of items selected from PSSC, CBA, and CHEMS published tests. Ten teachers who were familiar with the combined courses, and who had taught CBA chemistry, CHEMS chemistry, and/or PSSC physics, validated the test items, and only those items which received a unanimous vote were included as part of a test.[117] The physics control group received the physics pre- and post-tests, the chemistry control group received the chemistry pre- and post-tests, and the experimental groups took all four tests. An analysis of scores was made using the t-test. Results showed that there was no significant difference at the 5% level between the experimental and the control groups.[118] This result is qualified, however, by several factors.[119] Five of the experimental classes were taught by a teacher who had not had experience in either the physics or the chemistry content for which he was responsible. The mean IQ scores for the experimental groups were generally lower than the IQ scores of their counterparts in the control groups, and the mean grade placement of the experimental groups was lower than that of the control groups.

At the University of Chicago High School, a newly-developed combined course was compared to the general science course usually offered freshmen.[120] The Test on Understanding Science (TOUS), Form Jx, and a specially-written subject matter test (SMT) were given to students taking the combined course and to students taking the usual course, both as pre- and post-tests. Results indicated that the combined course was slightly more effective, based on TOUS results, but that based on SMT results, the usual course was more effective. The combined course was found to be highly effective in teaching about scientists as people, the nature of scientific theories, graph interpretation, computation, and the drawing of correct inferences from data. It was found weak in teaching definitions of technical terms such as "law," about general methods used by scientists, factual information, principals of animal classification, the distinguishing of interpretation and observation, and selection of information to support a scientific theory.

In 1962, a combined course developed at Barringer High School, Newark, New Jersey, was evaluated.[121] The control group took one year of physics followed by a year of chemistry, while the experimental group took the two-year course combining PSSC physics, CHEMS chemistry, and supplemental material. The control group was given the Dunning Physics Test at the end of the year's work in physics and the ACS Chemistry Test, form N, after the year's work in chemistry. The experimental group was given the same two tests at the completion of the two-year course. In addition, the Henmon-Nelson IQ Test Form A was administered to both groups. The results of these tests are summarized in Table 2 on the following page. In general it would seem that the combined course was slightly more effective than the two separately-taught courses, although the author of the report argued that the samples were too small to be statistically significant, and felt justified in claiming only that the combined course was no poorer than the two separate courses.[122] He additionally argues that it may not be valid to use the tests designed for separate courses to measure achievement in a combined course which may have different objectives, and points out that the combined course covered only two-thirds of the material in the chemistry text, which the chemistry test was designed to cover in its entirety, while the chemistry course covered the entire book.

A combined course at Catalina High School, Tucson, Arizona, covers one year's material in PSSC physics, one semester's material in algebra, and one semester's material in trigonometry, in one year by meeting for two hours a day.[123] After six weeks of class, the first unit PSSC test, form N, was administered to the combined class, as well as to a number of traditional classes, which were taught by another teacher. There was little difference between the average scores on the test for the two groups, despite the fact that the combined class had a lower over-all high school grade average.[124]

Table 2

Test Scores of Combined Course and Separate Course Students
Barringer High School

Test	Experimental Group (N=49)	Control Group (N=51)
IQ (Henmon-Nelson) Form A	Range = 99-134 Mean = 112	Range = 99-137 Mean = 116
Dunning Physics Test (Percentiles)	Range = 12-60 Mean = 30 (End of Sr. year)	Range = 46-87; Mean = 63 (End of Jr. year, just after taking physics)
		Range = 2-70; Mean = 21 (End of Sr. year, 1 yr. after taking physics)
ACS Chemistry Test Form N (Percentiles)	Range = 26-98 Mean = 55	Range = 22-98 Mean = 54

After Lerner, Morris R. Integrated Science: Physics and Chemistry. The Science Teacher. v. 31, #1, p. 37-8, Feb. 1964

A similar class, combining physics and calculus for two hours a day for one year, with the aim of helping academically-talented seniors prepare for advanced placement tests, was taken by nineteen students at Alamo Heights High School, Alamo Heights, Texas, in 1964-65. Results on the Advanced Placement Mathematics Test showed fourteen of sixteen students taking the test scored three or better, qualifying them for one year of advanced placement mathematics credit.[125] This is somewhat, although not dramatically, better than the previous year, when separate courses were used.

Finally, a two-year combined chemistry-physics course at E. O. Smith High School, Storrs, Connecticut, has produced students whose scores on College Entrance Examination Board physics and chemistry tests have been at least as good as would have been expected if those same students had taken the separate courses the school also offers.[126] It should be noted that a number of seniors took the tests in December, before having completed the course, and were therefore at something of a disadvantage.

Chapter 3

DISADVANTAGES OF COMBINED COURSES

As one author[127] has pointed out, combined courses have theoretical advantages but practical disadvantages. They are attractive pedagogically, but less attractive from the operational standpoint. As experience with combined courses grows, however, many of these difficulties are being overcome.

TEACHERS

One of the most commonly reported disadvantages of combined courses is that only a few outstanding teachers can acquire a satisfactory understanding of more than one of the traditional disciplines, and that even if he can become qualified in more than one discipline,[128] the traditionally-trained teacher finds it difficult to avoid thinking of them as separate and unrelated.[129]

The existence of this difficulty is disputed by a number of authors. One of them[130] points out that traditionally-trained teachers already teach in several subject areas in small schools, so teaching outside their areas does not present a problem to them, and that even if it did, they could use an existing combined course, teaching it nearly verbatim until they did become comfortable outside their area. Another[131] believes that it has already been demonstrated adequately that chemistry teachers, for example, can easily make the transition to a combined course and do an excellent job teaching it. Yet another[132] contends that the key to the problem lies in teacher motivation. A teacher who is highly motivated toward the introduction of a combined course will, it is contended, strengthen his own multidisciplinary background by self-directed study. The necessary motivation often develops when the teacher gets involved in the planning stages of the combined course.

It is evident, however, that a large number of people feel that the difficulty as stated does exist, since several means of avoiding it have been tried. Probably the most desirable of these, and the one which gets closest to the root of the problem, is training teachers specifically to teach combined courses. For example, in 1963, at Wisconsin State College, Eau Claire, Wisconsin, a program to train secondary teachers of mathematics and physics was begun.[133] A similar program for secondary physics and chemistry teachers was under development in 1971 at Southwest Minnesota State College, Marshall, Minnesota.[134] While not designed specifically with the teaching of combined courses in mind, programs such as these, and similar programs at other universities, which require a minimum of approximately 30 semester hours in each subject area, give the prospective combined-course teacher adequate subject-matter background. How much background is to be considered adequate is revealed by a 1966 survey of 19 secondary teachers of combined chemistry-physics courses.[135] Their own backgrounds, and the background they recommend for beginning combined-course teachers, summarized in Table 3, indicate that the thirty semester hour minimum in a subject area is more than adequate. Such courses, of course, do little to assure that the teacher does not still consider the disciplines as separate and distinct.

Table 3

Average and Recommended Academic Backgrounds of Teachers of Combined Physics-Chemistry Courses

Item	Physics	Chemistry	Biology	Earth Science	Teaching Experience (yrs)
Number of teachers responding	19	19	13	9	18
Mean semester hours possessed	27	37	10	7	13
Median semester hours possessed	33	22	8	5	15
Number of teachers recommending	19	19	12	9	--
Mean semester hours recommended	25	27	15	8	--
Median semester hours recommended	24	27	14	9	--

After George, Kenneth D., and Wrench, Susan H. "Are You Prepared to Teach a Course in Unified Science?" School Science and Mathematics, v. 66, #5, p. 429-36, May, 1966. Quoted in FUSE Bulletin, #1, December, 1966.

However, university programs designed with the training of teachers for combined courses exclusively, which can probably do more to alleviate this difficulty, appear to be rather rare. One such, for secondary teachers, is under development at the Educational Development Center,[136] but a survey in 1972 revealed just three universities with programs designed specifically to train combined course teachers.[137] Programs like those at Wisconsin State and Southwest Minnesota State are probably well able to provide an adequate number of reasonably well-trained secondary teachers, but there are apparently no programs available to train teachers of university-level combined courses.

For teachers who have already graduated, the problem of inadequate training can be alleviated by teacher training institutes. For example, the PSNS project has held summer institutes for the training of teachers who are to teach the PSNS combined course for the first time. A large part of the training has involved teaching physics to persons with a chemistry background, and chemistry to those with physics backgrounds.[138] The Portland Project established a teacher training program for Portland teachers who were to use their new course for the first time.[139]

The other major solution for the problem of one teacher being unable to cope with several subjects simultaneously is the use of team or cooperative teaching,[140] with a physics teacher teaching the physics aspect of the course, a chemistry teacher, the chemistry aspect, and so on. The literature abounds with examples of team-taught combined courses.[141, 142, 143, 144] This approach has the obvious advantage of assuring that there is a well-qualified teacher in each subject included in the course, and the obvious disadvantage that it tends to introduce a separation of subjects[145] that is totally at odds with the objectives of the course. As one author[146] points out, unless the teaching team exercises extreme caution, the team-taught course will tend to become laminated, essentially becoming several separate courses taught each among the others, rather than combined. Worse yet, since chemistry requires both mathematics and physics for proper understanding, and physics requires mathematics, while mathematics needs neither chemistry nor physics, the mathematics teacher can teach whatever area of mathematics he wishes without regard to the needs of physics or chemistry, and the physics teacher can teach whatever he wishes without regard to chemistry's needs. Teachers lower in the hierarchy have no leverage on those higher up, so eventually may decide it is easier to teach their part of the combined course as a separate course to achieve their own class goals, than to continue trying to teach part of a truly combined course.[147]

Another disadvantage of the team-teaching approach is that it makes scheduling of teaching assignments more difficult.[148, 149] Certainly the larger the number of teachers whose schedules must coincide at given times the more unwieldy is the administrator's task of making it so. Worse yet is the problem which may arise when specialist licensed teachers must be assigned to classes for which they are not licensed.[150] Nevertheless, these problems are ones which can usually be overcome, as witness the large number of team-taught combined courses.

TEXTBOOK

One disadvantage of combined courses frequently mentioned in the literature is the lack of a textbook suitable for such a course.[151, 152, 153, 154] This has lead a number of users of combined courses to use a traditional text for each subject included in the course; that is, both a physics book and a chemistry book for a physics-chemistry combined course, plus a syllabus of their own design, plus supplementary material from other sources.[155, 156] While this eclectic choice of materials may be desirable from the standpoint of broadening the students' outlook and allowing presentation of a topic from the source giving the best treatment of it,[157] it can be beyond a school's budget to buy several textbooks for a single course, especially if they are used in no other courses. Furthermore, the lack of a complete education package, including text, lab manual, tests, films, supplementary materials, teacher training institutes, and so on, seems to prevent many teachers from attaining the confidence necessary to depart from traditional course structures.[158]

The materials problem would seem to have been lessened in recent years with publication of materials developed by such national curriculum development groups as the Portland Project, NPSP, PSNS, and others, as well as publication of such combined course textbooks as Physics and Chemistry, A Unified Science,[159] and Physics and Chemistry, A Two-Year Course.[160] Additionally, syllabi of numerous locally-developed combined courses have been published in the literature, and are available for those who wish to use them.[161] Persons interested in further, or more recent information, are advised to make contact with the Center for Unified Science Education, The Ohio State University, 1460 West Lane Avenue, Columbus, Ohio, 43221. This organization's principal activities include:[162]

1. Establishing a working resource of combined science instructional materials and related literature for direct use by interested school groups.

2. Maintaining an up-to-date directory of combined science programs.

3. Conducting workshops on combined science education at different locations throughout the nation.

4. Preparing "remote workshop" packages for independent use by science departments or curriculum committees of individual schools.

5. Maintaining a "response system" to facilitate use of the Center's resources by interested individuals and groups both at the Center and by mail.

6. Producing a quarterly newsletter to describe Center resources, activities, and services, and as a vehicle for appropriate contributions to the literature of combined science education.

The Center for Unified Science Education (CUSE) was established in late 1972, and is operated by the Federation for Unification of Science Education (FUSE), which was itself founded in 1966. FUSE is now a professional association of science teachers allied to provide mutual support for the development of combined courses. Both CUSE and FUSE have been and continue to be important influences in the promotion of combined science courses at all levels, and of great assistance to those teachers wishing to initiate combined courses at their schools.

CONTENT AND SEQUENCING

The last major problem reported with combined courses is one which occurs to some extent with all courses: what material should be covered and in what order? The great temptation in a combined course is to try to cover too much.[163] The

Beloit Conference listed 23 general topics suitable for a combined physics-chemistry course, but pointed out that not all of them could be covered in a two-semester course.[164] Selection of topics to be covered, and selecting enough, but not too much, remains a problem.[165] Use of prepared curriculum guides and materials may make this somewhat easier, but the type of teacher who will adopt a combined course is probably also the type who will find it difficult to avoid adding "just a little bit extra."

Once the subject matter to be covered is chosen, the order in which it is to be covered must be determined. Particularly in the case of physics-mathematics combined courses, sequencing can be a nearly insoluble problem, as mathematics topics, particularly integrals and integration, are needed to develop the physics ideas long before a proper mathematical foundation has been laid.[166] Sometimes this can be dealt with by arranging the course so that integration of polynomials comes earlier than usual, while integration of more complicated functions is retained for a later date.[167] Several authors have[168, 169] for this reason, however, argued that mathematics should not be combined with other courses but should rather be prerequisite to them.

Two authors[170, 171] mentioned difficulties in their combined courses with transitions between topics in one subject and topics in another. Unless special care is taken to emphasize the combined aspects of the subjects, transitions from one to another may be confusing, particularly to the poorly-prepared student, but this would not appear to have been a problem in most courses and should be easily correctable.

LENGTH

Finally, it should be mentioned that combined courses, particularly on the secondary level, generally commit the student to a class of at least two, and sometimes three or even four years duration, compared to the one-year commitment of the usual course.[172] For the college-bound, or other student who would have taken several years of science, this presents no problem; but for the student who only wants one year of science, or who only wants to study one of the sciences included in the combined course, it is unfortunate. Some schools offer both separate and combined courses to meet the needs of the latter groups,[173] as well as the student who wants to study several sciences, but wants the option of stopping after one year, and students transferring from schools not having combined courses.[174]

Chapter 4

CHARACTERISTICS OF COMBINED COURSES

There are as many ways of organizing combined courses as there are teachers of those courses. Basically, however, almost all combined courses can be categorized as either integrated courses or unified courses.[175] An integrated course is one which results from putting together two or more previously separate subjects, such as chemistry and physics. Its organization would be along traditional lines, except that its subjects are developed jointly rather than separately. A unified course, on the other hand, attempts to view science as a whole. It will very likely include subject matter from quite a broad range of specialized sciences, for example, a combination of physics, chemistry, biology, astronomy, geology, and social sciences.[176] It will, by definition, be organized around one or more of the major concepts which permeate all the sciences, such as the nature of matter and energy,[177] scientific method,[178] orderliness, change, equilibrium, models, or quantification.[179] Both unified and integrated courses, however, fit into the rather broader category of combined course used in this paper.

Formats for combined courses generally fit into a rather small number of categories. On the college level combined courses reported in the literature range from a one-semester physics-mathematics course offered for humanities students,[180] through one- and two-year courses combining various disciplines, for science majors, non-science majors, or both,[181] up to four-year curricula combining physics and chemistry,[182] or physics and biology.[183] A 1966 survey showed[184, 185] that of combined courses designed for non-science majors, 22% were one semester long, 41% two semesters, 14% three semesters, and 21% four semesters. Seventeen percent required no lab work, 3% required one hour per week, 7% two hours per week, 35% required three hours per week, 21% required four hours per week, and 14% required more than four hours of lab work per week. (Percentages do not add to 100 due to rounding.) About one-third of the courses are terminal, while over half meet the prerequisites for more advanced courses. Seventy-five percent of the courses had fewer than fifty students enrolled.

With regard to combined courses for science majors, the same survey showed a mode of three hours lab work per week, with a significant number of courses requiring more, two-thirds of the courses serving as prerequisites for more advanced science courses, and most courses enrolling fewer than fifty students.

On the secondary level, courses reported in the literature ranged from a one-year, one-hour-per-day combined physics-chemistry course for humanities-oriented students,[186] through one-year, two-hour-per-day and two-year, one-hour-per-day combined physics-chemistry and physics-mathematics courses,[187] often for advanced placement students, to four-year, one-hour-per-day courses combining physics, chemistry, biology,[188] and in one case, earth science as well.[189] One course,[190] the NPSP course, was designed to maximize individual study through the use of 80 learning packages for single student use. Another[191] combined physics, chemistry, mathematics, and biology in a three-year, one-hour-per-day course with a historical orientation and organization. The one-year, two-hour-per-day courses were usually team taught by two teachers, the class being assigned to one teacher for one period, and then in the next consecutive period being assigned to the other, often in a contiguous room.

At neither level was comment encountered from anyone who had used several formats or organizations and preferred one to the others. Apparently the controlling factor in which format is used is the needs of the students.

Chapter 5

SUMMARY AND RECOMMENDATIONS

A number of theoretical advantages of combined courses have been discussed in this paper; a number of practical disadvantages have been discussed as well. The question now arising is whether or not the theoretical advantages of combined courses outweigh the practical disadvantages.

The effects of human nature have probably played a part in much of what has been written in praise of combined courses. Those persons writing about a combined course are often its developers. They are willing to give the course the benefit of the doubt because it is new, and minimize any difficulties with it on the theory that they will work themselves out in time. They are likely to overrate the new course simply because it is theirs. They are extremely unlikely to write any report of a course that is less than a success, so the picture that is presented is often unbalanced, with only reports of effective courses seeing print. A report of the theoretical advantages of a course is seen as scholarly and desirable, while a report of practical disadvantages is seen as indicating that the individual could not design a workable course, so far more advantages than disadvantages are reported. Indeed in most reports on combined courses advantages and praise make up much of the text, while disadvantages are relegated to a paragraph or two near the end.

The evaluations of combined courses reported in this paper are often largely subjective. Even the more objective evaluations are often made without a proper control, so that their value is reduced. The best-performed objective evaluations generally indicate only an indifferent superiority for combined courses. This conclusion is mitigated by three factors. First, it seems likely that the objectives of a properly-conducted combined class should be different from those of separately-taught classes. A test, if based on course objectives, as is proper, will not be valid in a class other than that for which it was written unless both classes have identical objectives. The tests used in most of the evaluations reported in this paper were designed for separately-taught classes, and thus when applied to combined classes measure only how well the combined class has met the objectives of the separately-taught classes, not how well the combined class has met its own objectives. Second, in educational research the number of variables is so enormous that proper experimental control is extremely difficult without the use of gargantuan samples. Many of the evaluations in this paper are based on samples whose size might be questioned. Finally, in the nature of the types of evaluations made, comparisons are made between one particular combined course, and two or more particular separately-taught courses. This type of comparison does not do more than indicate a trend in the relative superiority of combined and separate courses, *per se*. Most of the information garnered has to do with the relative superiority of several particular courses, one of which happens to be combined, and the others of which are separate.

On the other hand, it seems to this writer, that it is virtually unarguable that the goal of viewing science as a whole is highly desirable, and further that combined courses are more likely to achieve this goal than are separate courses. It is nearly inconceivable that compartmentalized science courses can foster other than a compartmentalized view of science. Admittedly much of the evidence in favor of combined courses may be specious, but the evidence certainly supports the contention that combined courses are at least as effective as separately-taught courses in terms of traditional academic measures of success. The advantages of combined courses may be overstated in large part, and the practical disadvantages may be understated, but it is this writer's opinion that the one undisputable advantage of combined courses, that they cause science to be viewed as a whole, is sufficient to outweigh the disadvantages. Practical disadvantages can be overcome, but separate courses will never foster a unified view of the world.

This writer concurs with the recommendation of the Wesleyan Conference,[192] that experiments in combined courses be performed in many, relatively small-scale, applications but with the further recommendation that extreme care be taken that all experiments are well-controlled, and that notice be taken of the fact that the goals of combined courses may be different from those of separate courses.

This writer is confident that a large number of trend-indicating experiments of this type will lend considerable support to the contention that combined science courses are generally superior to separate ones.

FOOTNOTES

1. Alberty, Harold Reorganizing the High School Curriculum, Revised edition, 1953, page 177, Macmillan, New York.

2. Ibid., p. 188.

3. Manning, Duane Toward a Humanistic Curriculum, 1971, page 27, Harper & Row, New York.

4. Leonard, J. Paul Developing the Secondary School Curriculum, 1946, page 242, Rinehart & Co., New York.

5. Ibid., p. 243.

6. Alberty, op. cit., p. 188.

7. Leonard, op. cit., p. 303.

8. "Improving the Quality and Effectiveness of Introductory Physics Courses." Report of a Conference sponsored by the American Association of Physics Teachers, American Journal of Physics, 25 (7) 417-24, Oct. 1957.

9. Burford, M. Gilbert, and Harry F. Lewis "The Wesleyan Conference of 1958--One Approach or Several." J. Chemical Education, 36 (2) 90-1, Feb. 1959.

10. Panel on Educational Research and Development Progress Report to the U. S. Commission of Education, Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology. March, 1964. Quoted in Prism II, 1(1)2, Autumn, 1972.

11. Stanlope, Roy W. "Four Years of School Science for All." The Science Teacher, 31(1)27-8, Feb., 1964.

12. Fuller, Edward C. "Multidisciplinary Courses for Science Majors." J. Chemical Education, 45 (9) 611-14, Sept., 1968.

13. Ibid.

14. Ibid.

15. Fuller, Edward C. "Recent Developments in the Teaching of Multidisciplinary Courses in Science." J. Chemical Education 44 (9) 542-4, Sept., 1967.

16. Ibid.

17. Goldsmith, Robert H. "Chemical Content of the Physical Science Course." J. Chemical Education 44 (10) 579-80, Oct., 1967.

18. Fuller, op. cit., see reference 8.

19. Prism II, 1 (1) 6, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

20. Ibid.

21. Haenisch, Edward L., and Lewis S. Salter "Integrated Introductory Course in Physics and Chemistry." J. Chemical Education, 35 (5) 246-7, May, 1958.

22. Klopfer, Leopold E. "Integrated Science for the Secondary School: Process, Progress, and Prospects." The Science Teacher, 33 (8) 27-31, Nov., 1966.

23. Fiasca, Michael "Unity of Science and Inquiry Method Emphasized." Science Education News, July, 1965, p. 1-2.

24. Fiasca, Michael, and David Porter "Portland Tries Integrated Science Course" The Science Teacher, 31 (1) 39, Feb., 1964.

25. Fiasca, op. cit., ref. 23.

26. McCurdy, Donald W., and Robert L. Fisher "A Program to Individualize Instruction in Chemistry and Physics." School Science and Mathematics, 71 (6) 508-12, June, 1971.

27. Ibid.

28. Wood, Elizabeth A. "The PSNS (sic) Project." J. Chemical Education, 46 (2) 69-70, Feb., 1969.

29. 'PSNS Staff' "Physical Science for Non-Scientists." Physics Today, 20 (3) 60-4, Mar., 1967.

30. Wood, op. cit.

31. Wood, op. cit.

32. Wood, op. cit.

33. National Science Board The Physical Sciences, Report submitted to Congress, 1970, p. 19-21. Quoted in FUSE Bulletin, #13, March, 1971, p. 4.

34. Fuller, Edward C., and R. Ronald Palmer "Teaching Physics and Chemistry in a Combined Course--A Report of the Beloit Conference." J. Chemical Education 39 (7) 346-7, July, 1962.

35. Ibid.

36. Dunlap, J. L., and A. P. Alberding "Interdepartmental Team Teaching--A Physics-Math (sic) Course." The Physics Teacher, 7 (3) 163-5, Mar., 1969.

37. Millstone, H. George "Guide for Teaching Chemistry-Physics Combined 1-2, 3-4 (PSSC - CHEMS)." ERIC ED024 604, 1966.

38. Haenisch and Salter, op. cit.

39. Fowler, John M. "The Interdisciplinary Curriculum" Physics Today, 21 (3) 58-61, March, 1968.

40. Fiasca, op. cit., ref. 23.

41. Fiasca and Porter, op. cit.

42. McCurdy and Fisher, op. cit.

43. Hayden, Mahlon F. "A Two-Year Integrated Physics-Chemistry Course." The Physics Teacher, 8 (3) 135-6, March, 1970.

44. Foerster, Paul A., and Joseph C. Buckley. "Physics and Calculus--Coordinated." The Texas Outlook 49 (12) 30-31, Dec., 1965.

45. Fuller, Edward C. "Combining First-Year Chemistry and Physics for Science Majors." J. Chemical Education, 41 (3) 136-8, March, 1964.

46. Pickar, Arnold D. "Core Course for Science Majors Combining Material from Physics, Chemistry, and Biology." American J. Physics 38 (2) 255-64, Feb., 1970.

47. Francis, Gladys M., and Casper W. Hill "A Unified Program in Science for Grades Nine through Twelve." The Science Teacher, 33 (1) 34-6, Jan., 1966.

48. Showalter, Victor "Unified Science--An Alternative to Tradition" The Science Teacher 31 (1) 24-6, Feb., 1964.

49. Fowler, op. cit.

50. Fehr, Howard "The Role of Physics in the Teaching of Mathematics." The Mathematics Teacher 56 (6) 394-9, Oct., 1963.

51. Ibid.

52. Fowler, op. cit.

53. Rosenbaum, Edward P. "Mathematics and Physics" Harvard Educational Review, 29 (1) 16-18, Winter, 1959.

54. Ibid.

55. Carpenter, Robert E. "How Much Mathematics Should be Required and Used in High School Physics." School Science and Mathematics 62 (5) 374-7, May, 1962.

56. Rosenbaum, op. cit.

57. Dunlap and Alberding, op. cit.

58. Foerster and Buckley, op. cit.

59. Ibid.

60. Fuller, op. cit., ref. 45.

61. Ibid.

62. Slesnick, Irwin L., and Victor Showalter "Program Development in Unified Science." The Science Teacher 28 (8) 54-5, Dec., 1961.

63. Fiasca and Porter, op. cit.

64. Haenisch and Salter, op. cit.

65. Fuller, op. cit., ref. 45.

66. Klopfer, op. cit.

67. Millstone, op. cit.

68. McCurdy and Fisher, op. cit.

69. Fuller and Palmer, op. cit.

70. Slesnick and Showalter, op. cit.

71. Ibid.

72. Showalter, op. cit., ref. 48.

73. Ibid.

74. Slesnick, Irwin L. "The Effectiveness of a Unified Science in the High School Curriculum." J. of Research in Science Teaching, 1, p. 302-14, 1963. Quoted in FUSE Bulletin, #2, p. 5, Jan., 1967.

75. Fuller, op. cit., ref. 45.

76. Fuller and Palmer, op. cit.

77. Magat, Phyllis L., and Wilfred H. Miller, Jr. "Development of Materials for a Fused Chemistry-Physics Course. Final Report." ERIC ED 014 422, May, 1967.

78. Fuller, op. cit., ref. 45.

79. Millstone, op. cit.

80. Fiasca, op. cit., ref. 23.

81. Pickar, op. cit.

82. Smith, Malcolm "Integrated Mathematics and Physics." The Mathematics Teacher, 48 (8) 535-7, Dec., 1955.

83. Slesnick and Showalter, op. cit.

84. Fuller, op. cit., ref. 45.

85. Fuller, op. cit., ref. 12.

86. Fuller, op. cit., ref. 15.

87. Wall, Edward "A New Course in College Physical Science." The Physics Teacher 9 (8) 458, Nov., 1971.

88. Haber-Schaim, Uri "Pre-Service Education of Physics-Chemistry Teachers." The Physics Teacher 9 (6) 324-5, Sept., 1971.

89. Welch, Wayne W. "Evaluation of the PSNS (sic) Course. II: Results." J. of Research in Science Teaching 9 (2) 147-56, 1972.

90. Haber- Schaim, op. cit.

91. Schultz, Frederick H. C. "A Physics-Mathematics Interdepartmental Major" The Physics Teacher 8 (6) 324-6, Sept., 1970.

92. Prism II, 1 (1) 6, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

93. Fuller, op. cit., ref. 12.

94. Haenisch and Salter, op. cit.

95. Magat and Miller, op. cit.

96. Bertke, Sister Mary Christopher "Covington Plan for Teaching High School Science" The Physics Teacher 9 (9) 530-1, Dec., 1971.

97. Ibid.

98. Ibid.

99. Ibid.

100. Fiasca, Michael "Evaluation of the Integrated Chemistry-Physics Course Developed by the Portland Project." Unpublished report (mimeographed), Portland State College, Portland, Oregon, 1965. Quoted in FUSE Bulletin, #4, April, 1967, p. 4.

101. Ibid.

102. Welch, Wayne W. "Evaluation of the PSNS (sic) Course. I: Design and Implementation." Journal of Research in Science Teaching, 9 (2) 139-45, 1972.

103. Young, David P. "From Newton to Energy and Matter: A Freshman Science Approach." J. of Chemical Education 47 (8) 580-1, Aug., 1970.

104. Fuller, op. cit., ref. 45.

105. Fuller and Palmer, op. cit.

106. Fowler, op. cit.

107. Pickar, op. cit.

108. Smith, op. cit.

109. Dunlap and Alberding, op. cit.

110. Ibid.

111. Pickar, op. cit.

112. Welch, op. cit., ref. 102.

113. Ibid.

114. Welch, op. cit., ref. 89.

115. Lowry, George G. "An Integrated Physics-Chemistry Curriculum for Science Majors." J. of Chemical Education 46 (6) 393-5, June, 1969.

116. Fiasca, op. cit., ref. 100.

117. Ibid.

118. Ibid.

119. Fiasca, op. cit., ref. 23.

120. Klopfer, Leopold E., and Donald C. McCann "Evaluation in Unified Science: Measuring the Effectiveness of the Natural Science Course at the University of Chicago High School." Science Education 53 (2) 155-64, Mar., 1969.

121. Lerner, Morris R. "Integrated Science: Physics and Chemistry." The Science Teacher 31 (1) 37-8, Feb., 1964.

122. Ibid.

123. Dunlap and Alberding, op. cit.

124. Ibid.

125. Foerster and Buckley, *op. cit.*

126. Hayden, *op. cit.*

127. Fowler, *op. cit.*

128. Fehr, *op. cit.*

129. McCurdy and Fisher, *op. cit.*

130. Goar, F. Darrell. Letter in *Prism II*, 1 (1) 7, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

131. Showalter, Victor "Chemistry in a Unified Science Curriculum." *School Science and Mathematics*, April 1967, p. 334-40. Quoted in *FUSE Bulletin*, #5, p. 4., July, 1967.

132. *FUSE Bulletin*, #1, p. 3, Dec., 1966.

133. Schultz, *op. cit.*

134. Bowman, Leo, *et al.* "A New Undergraduate Program for Future Physics-Chemistry Teachers" *J. of College Science Teaching* 1 (1) 47-9, Oct., 1971.

135. George, Kenneth D., and Wrench, Susan H. "Are You Prepared to Teach a Course in Unified Science?" *School Science and Mathematics*, 66 (5) 429-36, May 1966. Quoted in *FUSE Bulletin*, #1, December, 1966.

136. Haber-Schaim, *op. cit.*

137. *Prism II*, 9 (1) 6, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

138. 'PSNS Staff' "Physical Science for Non-Scientists" *Physics Today* 20 (3) 60-64, Mar. 1967.

139. Fiasca and Porter, *op. cit.*

140. Millstone, *op. cit.*

141. Fuller, *op. cit.*, ref. 45.

142. Magat and Miller, *op. cit.*

143. Pickar, op. cit.

144. Curriculum Report, 2 (1) 5-11, Dec., 1972. Published by the National Association of Secondary School Principals, 1201 16th St. N.W., Washington, D. C., 20036.

145. Fuller and Palmer, op. cit.

146. Fowler, op. cit.

147. Ibid.

148. Burford and Lewis, op. cit.

149. Fuller, op. cit., ref. 45.

150. Burford and Lewis, op. cit.

151. Fuller, op. cit., ref. 45.

152. Fuller and Palmer, op. cit.

153. Puri, Om P. "Cooperative General Science Project--A Progress Report." The Physics Teacher 9 (6) 320-3, Sept., 1970.

154. Simpson, Kenneth M., and John W. Sutton "Physics and Chemistry for General Education." J. of Chemical Education 29 (3) 133-6, Mar., 1952.

155. Hayden, op. cit.

156. Lowry, op. cit.

157. Fiasca and Porter, op. cit.

158. Showalter, op. cit., ref. 48.

159. Hogg, John C., et al. Physics and Chemistry, A Unified Science Books I and II. Princeton: D. Van Nostrand Company, Inc., 1960.

160. Committee on the Integration of CHEMS and PSSC (The). Physics and Chemistry, A Two-Year Course. Oregon. (This is the "Portland Project" textbook.)

161. See for example: Cassidy, Harold G. "A Natural Philosophy Course in Physics and Chemistry." J. of Chemical Education, 46 (2) 64-6, Feb., 1969; Francis and Hill, op. cit.; Klopfer, op. cit.; Magat and Miller, op. cit.; Millstone, op. cit.

162. Prism II, 1 (1)1, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

163. Fuller, op. cit., ref. 45.

164. Fuller and Palmer, op. cit.

165. Showalter, op. cit., ref. 48.

166. Foerster and Buckley, op. cit.

167. Ibid.

168. Carpenter, op. cit.

169. Rosenbaum, op. cit.

170. Fuller, op. cit., ref. 45.

171. Hayden, op. cit.

172. Showalter, op. cit., ref. 131.

173. Hayden, op. cit.

174. FUSE Bulletin, #1, Dec., 1966.

175. Prism II, 1 (1) 6, Autumn, 1972. Published by Center for Unified Science Education, Ohio State University.

176. Parsegian, V. Lawrence "Baccalaureate Science" Physics Today, 20 (3) 57-60, Mar., 1967.

177. Haenisch and Salter, op. cit.

178. Stanhope, op. cit.

179. Curriculum Report, 2 (1) 4, Dec., 1972. Published by National Association of Secondary School Principals, 1201 16th St. N.W., Washington, D.C.

180. Cassiday, op. cit.

181. See, for example: Fowler, op. cit.; Fuller, op. cit., ref. 12; Parsegian, op. cit.; Pickar, op. cit.; PSNS Staff, op. cit.; Puri, op. cit.

182. Lowry, op. cit.

183. "Disciplines Merge at Coventry." Physics Today 19 (4) 115, April, 1966.

184. Fuller, op. cit., ref. 12.

185. Fuller, op. cit., ref. 15.

186. Magat and Miller, op. cit.

187. See for example: Dunlap and Alberding, op. cit.; Foerster and Buckley, op. cit.; Hayden, op. cit.; Klopfer, op. cit.; Millstone, op. cit.; Smith, op. cit.

188. Slesnick and Showalter, op. cit.; Stanhope, op. cit.

189. Francis and Hill, op. cit.

190. McCurdy and Fisher, op. cit.

191. Bertke, op. cit.

192. Burford and Lewis, op. cit.

BIBLIOGRAPHY

Alberty, Harold. Reorganizing the High School Curriculum. Revised edition. New York: Macmillan, 1953.

Arons, A. B. "Anatomy of an Introductory Course in Physical Science," ERIC ED 062 113, 1972.

__________. "Anatomy of an Introductory Course in Physical Science," J. of College Science Teaching 1 (4) 30-4, April, 1972.

__________. "Structure, Methods, and Objectives of the Required Freshman Calculus-Physics Course at Amherst College," American J. of Physics 27 (9) 658-66, Dec., 1959.

Bassett, Lewis G. "For Nonscientists," Science Education News, July 1965, p. 3.

Berman, Louise M. New Priorities in the Curriculum. Columbus, Ohio: Charles E. Merril, 1968.

Bertke, Sister Mary Christopher, "Covington Plan for Teaching High School Science," The Physics Teacher 9 (9) 530-1, Dec., 1971.

Bowman, Leo, et al. "A New Undergraduate Program for Future Physics-Chemistry Teachers," J. of College Science Teaching 1 (1) 47-9, Oct., 1971.

Bunton, M. H. H. "Physical Sciences in a College of Education," Physics Education 5 (1) 50-3, Jan., 1970.

Burford, M. Gilbert and Harry F. Lewis, "The Wesleyan Conference of 1958--One Approach or Several," J. of Chemical Education 36 (2) 90-1, Feb., 1959.

Carpenter, Robert E. "How Much Mathematics Should be Required and Used in High School Physics," School Science and Mathematics 62 (5) 374-7, May, 1962.

Cassidy, Harold G. "A Natural Philosophy Course in Physics and Chemistry," J. of Chemical Education 46 (2) 64-6, Feb., 1969.

Cassidy, Harold G. "On Physics and Chemistry for the Non-Scientist," The Physics Teacher 9 (5) 267-9, May, 1971.

Committee on the Integration of CHEMS and PSSC (The). Physics and Chemistry, A Two-Year Course. Oregon.

Curriculum Report, 2 (1) 5-11, Dec., 1972. Published Quarterly by the National Association of Secondary School Principals, 1201 16th St. N.W., Washington, D.C., 20036.

"Disciplines Merge at Coventry," Physics Today 19 (4) 115, April, 1966.

Dunlap, J. L. and A. P. Alberding, "Independent Team Teaching--A Physics-Math (sic) Course," The Physics Teacher 7 (3) 163-5, March, 1969.

Fehr, Howard, "The Role of Physics in the Teaching of Mathematics," The Mathematics Teacher 56 (6) 394-9, Oct., 1963.

Fiasca, Michael, "The Evaluation of the Integrated Chemistry-Physics Course Developed by the Portland Project." Unpublished report (Mimeographed), Portland State College, Portland, Oregon, 1965. Quoted in FUSE Bulletin, #4, April, 1967, p. 4.

__________. "Unity of Science and Inquiry Method Emphasized," Science Education News, July, 1965, p. 1-2.

__________ and David Porter, "Portland Tries Integrated Science Course," The Science Teacher 31 (1) 39, Feb., 1964.

Foerster, Paul A. and Joseph C. Buckley, "Physics and Calculus--Coordinated," The Texas Outlook, 49 (12) 30-1, Dec., 1965.

Fowler, John M. "The Interdisciplinary Curriculum," Physics Today 21 (3) 58-61, Mar., 1968.

Francis, Gladys M. and Casper W. Hill, "A Unified Program in Science for Grades Nine Through Twelve," The Science Teacher 33 (1) 34-6, Jan., 1966.

Fuller, Edward C. "Combining First Year Chemistry and Physics for Science Majors," J. of Chemical Education 41 (3) 136-8, Mar., 1964.

__________. "Multidisciplinary Courses for Science Majors," J. of Chemical Education 45 (9) 611-14, Sept., 1968.

__________. "Recent Developments in the Teaching of Multidisciplinary Courses in Science," J. of Chemical Education 44 (9) 542-4, Sept., 1967.

__________ and R. Ronald Palmer, "Teaching Physics and Chemistry in a Combined Course--A Report of the Beloit Conference," J. of Chemical Education 39 (7) 346-7, July, 1962.

FUSE Bulletin, Nos. 1-13. Published by Federation for Unified Science Education, Ohio State University, Columbus, Ohio, 1966-1971.

George, Kenneth D., and Susan H. Wrench," Are you Prepared to Teach a Course in Unified Science?" School Science and Mathematics 66 (5) 429-36, May, 1966. Quoted in FUSE Bulletin, #1, Dec., 1966.

Goar, F. Darrell. Letter in Prism II, 1 (1) 7, Autumn, 1972, Center for Unified Science Education, Ohio State University, Columbus.

Goldsmith, Robert M. "Chemical Content of the Physical Science Course," J. of Chemical Education 44 (10) 579-80, Oct., 1967.

Haber-Schaim, Uri, "Pre-Service Education of Physics-Chemistry Teachers," The Physics Teacher 9 (6) 324-5, Sept., 1971.

Haenisch, Edward L., and Lewis S. Salter, "Integrated Introductory Course in Physics and Chemistry," J. of Chemical Education 35 (5) 246-7, May, 1958.

Hayden, Mahlon F. "A Two-Year Integrated Physics-Chemistry Course," The Physics Teacher 8 (3) 135-6, March, 1970.

Hoffmann, Richard L. and Doris K. Kolb, "An Approach to Teaching Physical Science," J. of Chemical Education 47 (5) 383-5, May, 1970.

Hogg, John C. et al. Physics and Chemistry, A Unified Science Books I and II. Princeton: D. Van Nostrand Company, Inc., 1960.

"Improving the Quality and Effectiveness of Introductory Physics Courses." Report of a Conference sponsored by The American Association of Physics Teachers. American J. of Physics 25 (7) 417-24, Oct., 1957.

Kelsey, Kenneth W. "Exercises in Computer-Assisted Physics and Mathematics," School Science and Mathematics 67 (2) 119-123, Feb., 1967.

Klopfer, Leopold E. "Integrated Science for the Secondary School: Process, Progress, and Prospects," The Science Teacher 33 (8) 27-31, Nov., 1966.

Klopfer, Leopold E. and Donald C. McCann, "Evaluation in Unified Science: Measuring the Effectiveness of the Natural Science Course at the University of Chicago High School," Science Education 53 (2) 155-164, March, 1969.

Leonard, J. Paul. Developing the Secondary School Curriculum. New York: Rinehart & Co., 1946.

Lerner, Morris R. "Integrated Science: Physics and Chemistry," The Science Teacher 31 (1) 37-8, Feb., 1964.

Lowry, George G. "An Integrated Physics-Chemistry Curriculum for Science Majors," J. of Chemical Education 46 (6) 393-5, June, 1969.

Magat, Phyllis L. and Wilfred H. Miller, Jr. "Development of Materials for a Fused Chemistry-Physics Course. Final Report." ERIC ED 014 422, May, 1967.

Manning, Duane. Toward a Humanistic Curriculum. New York: Harper & Row, 1971.

McCurdy, Donald W. and Robert L. Fisher, "A Program to Individualize Instruction in Chemistry and Physics," School Science and Mathematics 71 (6) 508-12, June, 1971.

__________. "Physical Science Project... (sic) An Individualized Two-Year Chemistry-Physics Course," The Science Teacher 36 (9) 60-63, Dec., 1969.

Millstone, H. George, "Guide for Teaching Chemistry-Physics Combined 1-2, 3-4 (PSSC-CHEMS)," ERIC ED 024 604, 1966.

Muessig, Raymond H., editor. Youth Education: Problems/Perspectives/Promises. Association for Supervision and Curriculum Development, NEA, Washington, D.C., 1968.

National Science Board. The Physical Sciences, Report submitted to Congress, 1970, p. 19-21. Quoted in FUSE Bulletin, #13, March, 1971, p. 4.

Panel on Educational Research and Development; Progress Report submitted to the U. S. Commission of Education, Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology. March, 1964. Quoted in Prism II 1 (1) 2, Autumn, 1972.

Parsegian, V. Lawrence, "Baccalaureate Science," Physics Today 20 (3) 57-60, March, 1967.

Pickar, Arnold D. "Core Course for Science Majors Combining Material from Physics, Chemistry and Biology," American J. of Physics 38 (2) 255-64, Feb., 1970.

Prism II, 1 (1) 6, Autumn, 1972. Published Quarterly by the Center for Unified Science Education, Ohio State University, Columbus.

PSNS Staff, "Physical Science for Non-Scientists," Physics Today 20 (3) 60-4, March, 1967.

Puri, Om P. "Cooperative General Science Project--A Progress Report," The Physics Teacher 9 (6) 320-3, Sept., 1970.

Rochow, E. G. "A Coordinated Program for Teachers of Chemistry and Physics," American J. of Physics 21 (7) 559-60, Oct., 1953.

Rosenbaum, Edward P. "Mathematics and Physics," Harvard Educational Review 29 (1) 16-18, Winter, 1959.

Rubin, Louis J., editor. Life Skills in School and Society. Association for Supervision and Curriculum Development, NEA, Washington, D.C., 1969.

Schultz, Frederick H. C. "A Physics-Mathematics Interdepartmental Major," The Physics Teacher 8 (6) 324-6, Sept., 1970.

Showalter, Victor, "Chemistry in a Unified Science Curriculum," School Science and Mathematics, p. 334-40, April, 1967. Quoted in FUSE Bulletin, #5, p. 4, July, 1967.

__________. "Unified Science--An Alternative to Tradition," The Science Teacher 31 (1) 24-6, Feb., 1964.

Simpson, Kenneth M., and John W. Sutton, "Physics and Chemistry for General Education," J. of Chemical Education 29 (3) 133-6, March, 1952.

Slesnick, Irwin L. "The Effectiveness of a Unified Science in the High School Curriculum," J. of Research in Science Teaching v. 1, p. 302-14, 1963. Quoted in FUSE Bulletin, #2, p. 5, January, 1967.

__________ and Victor Showalter, "Program Development in Unified Science," The Science Teacher 28 (8) 54-5, Dec., 1961.

Smith, Malcolm, "Integrated Mathematics and Physics," The Mathematics Teacher 48 (8) 535-7, Dec., 1955.

Smith, Melvin O. "General Physical Science at the College Level," School Science and Mathematics 70 (8) 737-8, Nov., 1970.

Spice, J. E. "The Nuffield Physical Science Course," Physics Education 7 (2) 71-4, Feb., 1972.

Stanhope, Roy W. "Four Years of School Science for All," The Science Teacher 31 (1) 27-8, Feb., 1964.

Wall, Edward, "A New Course in College Physical Science," The Physics Teacher 9 (8) 458, Nov., 1971.

Welch, Wayne W. "Evaluation of the PSNS (sic) Course. I: Design and Implementation,' J. of Research in Science Teaching 9 (2) 139-45, 1972.

__________. "Evaluation of the PSNS (sic) Course. II: Results," J. of Research in Science Teaching 9 (2) 147-56, 1972.

Wilson, L. Craig. The Open Access Curriculum. Boston: Allyn and Bacon, 1971.

Wood, Elizabeth A. "The PSNS (sic) Project," J. of Chemical Education 46 (2) 69-70, Feb., 1969.

Worthing, Robert, "Physics and Chemistry for the Automotive Trades," ERIC ED 013 308, Jan., 1967.

Young, David P. "From Newton to Energy and Matter: A Freshman Science Approach," J. of Chemical Education 47 (8) 580-1, Aug., 1970.

COMBINED SCIENCE COURSES

by

DONALD MCLEAN TROTTER, JR.

B. S., Kansas State University, 1971

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Physical Science Teaching

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Combining several usually separate courses into one broader course to make the learned material more functional in the life of the learner, promote easy transfer, and take into account the psychological principle of securing mass impressions and large overviews of patterns before details are discussed, has long been advocated. In the science area, the idea of combining physics with chemistry and/or mathematics has stimulated interest and effort. Literature was examined to determine what advantages, disadvantages, and characteristics had been reported, in the science area, for such "combined courses," when compared to separately-taught courses. Advantages claimed for combined courses were found to be:

1. Elimination of the duplication and repetition of subject matter which occurs when teachers in separate courses must teach the same or similar topics.

2. Combining courses insures inclusion of material from all disciplines necessary to understand a topic.

3. Such courses give a broad overview of the theoretical framework of science, rather than the compartmented view fostered by separate courses.

4. Combined courses provide the opportunity for deeper study of a variety of topics.

5. Such courses give the type and depth of background desirable for prospective teachers.

6. Combined courses increase student interest in science.

7. Such courses enable college students to make a wiser, earlier choice of major, since they are exposed to several disciplines sooner than usual.

8. Combined courses allow longer continuous study of an area or topic.

9. Students in a combined course develop a class spirit.

Reported disadvantages of combined courses were:

1. It is difficult for teachers to understand several disciplines. This is disputed by several authors, and it is pointed out that team teaching, and new training programs for combined course teachers can obviate this problem.

2. There is a lack of textbooks suitable for combined courses. Recently-developed materials would seem to be eliminating this problem as well.

3. It is difficult to choose content and determine sequencing. This is, however, a problem most separately-taught courses encounter as well.

4. Combined courses, in many cases, commit the student to a course of study two or more years long, as opposed to the one-year commitment usual with separately-taught courses.

Combined courses on both the college and secondary levels were found to range from one semester to four years in length. Secondary level courses often met for one hour a day for two years, or two hours a day for one year. Courses designed for science majors, non-science majors, and for both together were reported.

Evaluations of combined courses were generally favorable, although largely subjective. The most nearly objective evaluations, however, would seem to indicate only an indifferent superiority for combined courses over separate courses in terms of traditional academic measures of success. This writer urges further, better-controlled experimentation in the area of combined science courses, since it is felt that the experiments conducted to date have been inadequately controlled and did not take sufficient notice of the difference in goals of combined and separate courses.