THE PROBLEM OF THE INTEGRATION OF THE PHYSICAL SCIENCES FOR THE LATER YEARS OF THE HIGH SCHOOL

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Chapter I

THE PROBLEM OF THE REORGANIZATION OF THE PHYSICAL SCIENCES FOR THE HIGH SCHOOL

A Brief History of Physical Science in American Secondary Schools

In the Latin grammar schools of New England, the first American secondary schools, physical science had little or no place. Surveying and navigation were introduced to these schools, particularly in sea-port towns, and in small amounts, by the middle of the eighteenth century. These subjects represented an approach to physical science but are better classified as branches of mathematics.[1]

Science teaching in American secondary schools really began with the establishment of the academies. In 1743, Benjamin Franklin named astronomy, geography and natural history as subjects for the Franklin Academy, which was instituted in 1751 as the first American academy.[2] Of the physical sciences, natural philosophy, astronomy, physics, geography and chemistry were taught in the numerous academies which were established in the second half of the eighteenth and first

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[1] Monroe, "A Brief Course in the History of Education", The Macmillan Company, New York, 1907, p. 365-366.

[2] Montgomery, "A History of the University of Pennsylvania, 1749-1770", George W. Jacobs and Company, Philadelphia, 1900, p. 497-500.

half of the nineteenth centuries. [3] Geography was almost universally taught in the academies, with natural philosophy and astronomy second in frequency [4], and the latter closely related to mathematics. [5]

The first high schools followed the lead of the academies with regard to physical science. In the first American high school, The English Classical School, Boston, 1821, geography was taught in the first year, navigation and surveying in the second, and natural philosophy, with astronomy, in the third year. [6]

Early science teaching was almost entirely by the textbook method; a little of demonstration work gradually developed, but the laboratory method was not used. [7] These textbooks increased rapidly in numbers. In 1804, six textbooks in geography represented the total list of science books of any sort published in the United States; in 1832, the list comprised: geography, 39 different textbooks; astronomy, 11; natural philosophy, 6; chemistry, 5. [8]

The practical aim of utility prevailed in the earlier science teaching [9]; later, science study for liberal culture and for training in scientific methods were emphasized, as well as its usefulness. [10]

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[3] Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 18.

[4] Monroe, Paul. loc. cit.

[5] Brown, "The Making of Our Middle Schools", Longmans, Green and Company, New York, 1902, p. 232-233.

[6] Graves, "A History of Education in Modern Times", The Macmillan Company, New York, 1913, p. 349-351.

[7] Graves, F. P. loc. cit.

[8] Monroe, Paul. loc. cit.

[9] Graves, F. P. loc. cit.

[10] Brown, E. E. loc. cit.

In 1807, geography was required for entrance to Harvard College; this was followed by physics in 1872, and by physical geography in 1876.[11] After 1870, there was recognition of physical sciences for entrance to colleges and universities.

Beginning with 1870, the number of science courses offered in high schools multiplied rapidly[12]; these courses were short, informational and superficial. From the start there was a strong tendency to overload the high school curriculum with science subjects because of the emphasis upon science by the academies, and because science was soon required for teachers' examinations and certificates.[13] At this time, physical geography, chemistry, geology, astronomy and natural philosophy were commonly taught in the high schools.[14] Short courses in physics and chemistry gradually displaced natural philosophy.

Largely through the influence of the Committee of Ten on Secondary School Studies, 1893, the brief courses in physical science were lengthened to courses of one year, or at least one-half year, and laboratory methods were introduced.[15] By 1900, geology and astronomy were no longer typical courses in American high schools.[16] From 1860 to 1911, the amount of science, measured in years, offered in the

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[11] Monroe, Paul. loc. cit.

[12] Brown, E. E. loc. cit.

[13] Graves, F. P. loc, cit.

[14] Koos, "The American Secondary School", Ginn and Company, Boston, 1927, p. 414-417.

[15] Douglass, A. A. op. cit., p. 134.

[16] Koos, L. V. loc. cit.

high schools of the North Central states was doubled, and mainly by the lengthening of courses. [17]

Since 1910, there has been a gradual supplanting by introductory general science, of physical geography and physiography. [18] At this time, for the physical sciences, general science, physics and chemistry are the emphasized offerings of American high schools, largely due to the influence of the Commission on Reorganization of Secondary Education of the National Education Association. [19] In a small percentage of high schools, household chemistry and physics are taught as special courses for girls [20], while for boys, applied electricity or agricultural physics may be offered; the tendency to differentiate courses is more evident in larger high schools.

In 1925, for 678,935 students in 1571 North Central public high schools, 295,044 were enrolled in science subjects. The percentage of this enrollment for the different subjects was as follows: [21]

General Science	26.4 %
Physical Geography	12.1
Botany & Zoology	21.8
Physics	19.6
Chemistry	20.1 %

Few students in these North Central high schools study more than one year of science, in addition to general science. The second

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[17] Uhl, "Secondary School Curricula", The Macmillan Company, New York, 1927, p. 187-188.

[18] Douglass, A. A. op. cit., p. 258.

[19] Reorganization of Science in Secondary Schools. Department of the Interior, Bureau of Education, Bulletin, 1920, No. 26.

[20] Koos, L. V. loc. cit.

[21] Uhl, W. L. op. cit., p. 535-536.

year usually consists of biology, physics or chemistry.[22]

According to Hunter's investigation[23], the total offering in science courses in high schools increased from 1908 to 1923, measured in hours of work done. Koos[24] has stated that, aside from a slump in physics and physical geography, the pupil enrollment in high school science courses has held its own from 1910 to 1922. Table I shows the findings of the Bureau of Education for percentages of students enrolled in high school science subjects from 1890 to 1922:[25]

Table I

Percentage of Students in High School Taking Science Subjects

	1870	1895	1900	1905	1910	1915	1922
Astronomy		4.79	2.78	1.22	.53	.28	.07
Physics	22.21	22.77	19.04	15.66	14.61	14.23	8.93
Chemistry	10.10	9.15	7.72	6.76	6.89	7.38	7.40
Physical Geography		23.89	23.37	21.52	19.34	14.58	4.28
Geology		5.00	3.61	2.34	1.16	.48	.16
General Science							18.27
Biology						6.90	8.78

22 Uhl, W. L. loc. cit.

23 Hunter, G. W. The Place of Science in the Secondary School. The School Review, Vol. XXXIII (1925), p. 370-371, 453-456.

24 Koos, L. V. op. cit., p. 358.

25 Statistics of Public High Schools. Department of the Interior. Bureau of Education, Bulletin No. 7, 1924, p. 46.

The history of physical science in American secondary schools reveals certain trends of development of these subjects:

(1) The early sole aim of utility in daily life and the vocations gradually came to share consideration with the aim of science for cultural education, and also a preparation for college and university science.

(2) Short specialized courses were constructed out of more general subjects like natural philosophy and these, in turn, were lengthened to year or semester courses.

(3) The total offering in years of the high school course has been increased until a four years' offering in science is fairly common in the American high schools.

(4) In recent years, there has been a strong tendency toward reorganization of the offerings of the first year of high school, with the result that general introductory science is well established in the eighth or ninth grade.

(5) High school science courses have gained acceptance for entrance by credit or examination by even the more conservative colleges and universities.

(6) General science, physics and chemistry are now the principal subjects in the physical sciences offered in American high schools.

(7) High school graduates commonly take one other science, besides general sciences, before graduation.

(8) Aside from general science, and to a lesser degree

biology, the science offerings of the typical American high school are not patronized by large numbers of students. Physics has constantly enrolled smaller and smaller percentages of pupils, while chemistry has barely held its own for several years. [26]

The Need for a Reconstruction of the Physical Sciences

The experience of teaching the physical sciences for several years in high schools, the further experience as a high school principal, together with observation of science work in many schools, and some reading and reflection on the subject over a period of years, have led to the conclusion that one of the most pressing problems of instruction in the physical sciences in high school is the problem of reconstruction of these courses in such a way as to provide better for the needs, interests and activities of American boys and girls.

The two leading subjects of the physical sciences, chemistry and physics, as commonly taught, do not well meet these needs, fail to arouse adequate interest, and are unrelated, in large measure, to the activities of average boys and girls. College born subjects, as they are, and reflecting the fields of special research in science, rather than an organization based upon learning and teaching, they are too difficult and too remote from ordinary human experiences, to furnish a fair return to the typical high school student, however industrious and persistent he

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[26] Douglass, A. A. op. cit., p. 404.

may be. At a time when the applications of physics and chemistry are without a parallel in the world's history in the closeness of their relations to the life of the average individual, they are unsought by large numbers of the pupils in our schools.

The success of general science and progressive courses in biology has pointed the way to meet this need through an integration, or unification, of selected materials from the specialized fields of physical science. The pupil enrollment in general science is twice as large as that of any other high school science; where botany and zoology have been reorganized into a unified course in biological science, increase in enrollment and popularity have been the rule.

Such a course in unified physical science should be distinguished from the general science offering of the eighth or ninth years. Occupying a place in grade eleven or twelve, its position there relative to general science would be similar to the position now held by modern biological science in grade ten. Both represent a step forward in specialization from ninth grade general science, but not such a wide step as the highly specialized subjects of traditional physics and chemistry necessitate, and which accounts, in part, for the comparative unsuitability of these subjects to high school students. By this plan, the science curriculum of the high school would stand in this form:

First year, general science
Second year, biological science
Third or fourth year, physical science

This course would be in line, historically, with the tendency toward generalized courses in the high school subjects, as exemplified in general science and biology, as well as by general mathematics, general social science, general English courses, etc. General social science, particularly, in grades eleven or twelve as "problems of democracy" and the like, affords ample justification from the standpoint of the historical, or traditional.

The undesirable results of the conditions now prevailing in the high school where students graduate, typically, with a course in general science followed by only one specialized science, would be eliminated, at least in part. A more general course, drawing from all of the physical sciences matters most valuable to the average graduate, would tend to reduce the effect of a one-sided concentration in a narrow field, with consequent ignorance of related fields.

Such a course would be aimed to meet the needs of the average, educated layman who finds in his daily life need for the facts, principles, methods and attitudes of modern physical science. In a civilization which, more than anything else, shows the results of physical science in service to man, there would be considerable justification for requiring a general course in physical science for the majority of high school graduates. For the traditional, specialized course in physics or chemistry, aimed toward college science and direct vocational preparation for research in pure or applied science, the present situation, where seven or eight per cent of high school graduates elect physics or chemistry, is about all that can be reasonably expected. Without prescribed entrance credits in physics or chemistry set up by the colleges and universities, and without the pressure which is exerted within the high schools themselves to fill the physics and chemistry classrooms, the election of physics and chemistry would probably be limited to some three or four per cent of high school students, unusually intelligent, or else possessed of natural abilities for physical science.

A course in general physical science would have the effect of reducing the number of separate subjects now taught in the high schools - a result which would furnish some relief to a situation which becomes increasingly a more severe economic and administrative burden to the public and school officials. Especially in the smaller schools, which includes the vast majority of American high schools [27], such a course would solve vexatious problems of alternation of subjects, maintenance of separate laboratories for physics and chemistry, etc.

In the larger high schools, where the number of courses offered is relatively unimportant, the course might be offered alongside traditional courses in physics or chemistry, the latter being restricted to the meeting of college entrance requirements, and the former open to the great majority of prospective graduates who need preparation for life instead of preparation for college physics or chemistry. Eventually, college recognition might be received for such a course in view of the fact that recognition has already been gained for many of the general courses now established in high schools, and,

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[27] Cook, "High School Administration", Warwick & York, Inc., Baltimore, 1926, p. VII.

especially, because of the fact that college offerings in first year physics and chemistry are, in considerable part, duplications of the high school subjects. It might be found that the best sort of preparation for college science would be the general course in physical science.

A course in unified physical science for the junior or senior years of high school, to the radically inclined, would be but a moderate step in the direction of a comprehensive, integrated curriculum in science covering all four years of high school, somewhat after the plan of a good curriculum in English; it is such a step forward, however, that hostility would possibly not be aroused among the conservatives in high school education, who prefer to proceed with caution, even toward theoretically ideal conditions.

Statement of the Problem

For more adequately meeting the needs of the average layman who will never pursue science in college, for the great majority of boys and girls who go out from the high schools with insufficient training in physical science to meet life conditions which are tremendously influenced by modern physical science, and for the ninety per cent of smaller high schools in the United States which limit their offerings in science, what would be the value of an integrated course in physical science for grade eleven or twelve? Could such a course, unified under certain comprehensive principles, and made up of selected materials from the commoner physical sciences, be constructed? In outline, what would such an integration be like?

By hypothesis, through selection of curricular materials from the specialized fields of physical science, the tentative outline of a single, general organization could be formulated; this outline would represent the organization of the facts and generalizations of the physical sciences around objectives and activities for learning and teaching; principles of integration, or unification, could be discovered and used; the objectives and activities would be adapted to the experiences, interests and abilities of pupils in the senior or junior years of high school; such an organization would reflect modern theories and tendencies in the selection, arrangement and presentation of subject matter to relatively immature and non-specialized learners; it would more adequately meet the average needs of present-day youth and educated laymen in the physical sciences.

The Procedure

By means of a questionnaire, an investigation of the interests of high school students in the physical sciences was made. In the preparation of the question sheet, lists of suggestive items, or questions, were avoided in order to make sure of an unguided response. Both interesting and uninteresting items were called for on the sheet. The questionnaire was sent to both boys and girls in high schools, to large and small schools, and to urban and rural schools.

The same questionnaire was filled out by a limited number of adults, who were for the most part teachers, or prospective teachers. In all cases, data were secured from individuals who had studied the physical sciences in schools, and principally in high schools.

Similar investigations of the interests in physical science of elementary school pupils, junior high school pupils and adults, were examined in professional magazines, books, and theses. Tabulations were made and conclusions drawn in the light of all of the data.

A thorough study was then made of the psychology of interest, as applied to high school science teaching, in standard works on psychology and educational psychology. Finally, conclusions were established for the function of interest in construction of a course of study in secondary school physical science.

A special investigation was made to reveal the current aims of physical science in high schools. As a first step, a general inquiry was addressed to colleges of education, or departments of education, in all state universities, to similar colleges or departments in other prominent universities, and to all state departmentx of education, in order to secure (1) the names of the most outstanding science teachers in the different states, and (2) information concerning the most recent developments in science courses of study ih the states. Later, a request to submit a list of general aims for physical science in the high school was sent to a large number of these most competent science instructors in high schools, normal schools, teachers' colleges and universities. Both men and women instructors in all of the special physical sciences were included, as well as professors of science education in university departments and colleges of education.

From the replies secured, a list of the current aims for high school physical science was drawn up; additions to this list were made from science courses of study secured from the majority of the states, from larger cities, and from particular localities conspicuous for course of study revision. Final additions were secured from professional writings of educators and science teachers in articles in magazines and books, from bulletins, pamphlets, syllabi, and personal letters received from numerous individuals. All recent textbooks on the teaching of physical science and a few hundred magazine articles were examined.

The complete list was then checked for the aims of greatest importance by professors of science education, city supervisors of high school science, and graduate students in science education. Finally, a study was made of all similar investigations of merit, and conclusions drawn concerning current aims in teaching high school physical science.

The philosophy of secondary school science, as found in the writings of leading authorities on the theory of modern education, was next investigated, the values of a unified course in physical science established, the possibilities of construction of such a course considered, and principles of integration formulated.

Criteria for the evaluation and selection of curricular materials were derived from the philosophy of science teaching in the secondary school, the psychology of interest in respect to science, from the conclusions of the investigations of current aims, and from the interests of high school students in the physical sciences. These criteria were employed in the construction of a tentative outline of integrated materials in physical science for grade eleven or twelve of the high school.

The following special fields of physical science were utilized:

(1) physics
(2) chemistry
(3) astronomy
(4) meteorology
(5) mineralogy
(6) physical geography
(7) physical geology

Basic treatises in these special sciences, articles in professional and scientific journals, all recent high school textbooks, and a large number of late state and city courses of study in these sciences were then analyzed for specific objectives and activities. Lists of these were drawn up for each special science and submitted for rating to outstanding teachers in high schools, normal schools, teachers' colleges and universities. In every case the instructor was given a list of items in his own field of study and teaching, and requested to check the essentially important items for teaching that subject in the junior or senior year of high school. By way of supplement, a search was made for especially noteworthy and scientific curricular contributions from progressive centers throughout the country. Before inclusion in the tentative outline of the synthesis, these objectives and activities were submitted to the test of the criteria mentioned above.

Thus, all objectives and activities, in the ultimate analysis, were evaluated and selected on the following bases:

(1) Criteria devised from the philosophy of education

(2) Criteria devised from the psychology of interest

(3) Judgment of expert instructors in the physical sciences

(4) Judgment of specialists in science education

(5) Authoritative works in the physical sciences

Similarly, by way of summary, essential subject matter in the form of activities, objectives, etc., were derived from the following sources:

(1) Modern textbooks in the physical sciences

(2) Recent courses of study

(3) Standard treatises in the physical sciences

(4) Other scientific writings in periodicals, bulletins, etc.

Finally, the tentative outline of a unification of the physical sciences was formulated in terms of:

(1) General aims

(2) Specific objectives to be attained

(3) Pupil activities

(4) Teaching procedures

Chapter II

THE INTERESTS OF PUPILS AND ADULTS IN THE PHYSICAL SCIENCES

Interests of High School Students

Interests in the physical sciences of high school students were investigated by a questionnaire [1]. The question sheet was formulated with the aim of securing a free and unguided expression of interests from the pupils; no list of items for checking, or suggestive questions, were employed. Data were secured from 1016 students in 26 different high schools. The high schools were located in 21 towns and cities of six states [2]. Of the 1016 pupils, 536 were boys and 480 were girls.

In Tables II-V, following, are presented the chief interests and their opposites, very uninteresting matters, arranged for boys and girls separately, and according to the subjects studied:

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1 See Appendix A.

2 See Appendix B.

Table II

Chief Interests of 536 High School Boys in the Physical Sciences. *

Subject		Topic	Frequency of Mention
I. Astronomy	1.	Astronomy	38
	2.	Planets	28
	3.	Stars	27
	4.	Solar system	11
	5.	Moon	9
II. Chemistry	1.	Experiments	64
	2.	Analysis	43
	3.	Various elements	35
	4.	Chemistry	25
	5.	Atoms and molecules	23
	6.	Carbon and its compounds	18
	7.	Dyeing	18
	8.	Problems	17
	9.	Iron family	17
	10.	Periodic law	15
III. Geology	1.	Rocks	16
	2.	Geology	12
	3.	Coal	8
	4.	Origin of earth	7
	5.	Land forms	6
IV. Meteorology	1.	Weather	16
	2.	Climate	10
	3.	Winds	5
V. Physical Geography	1.	Geography	7
	2.	Maps	6
VI. Physics	1.	Electricity	252
	2.	Magnetism	90
	3.	Sound	78
	4.	Light	70
	5.	Mechanics	63
	6.	Fluid pressure	50
	7.	Engines	43
	8.	Heat	31
	9.	Gravity	28
	10.	Radio	26
VII. General interest	1.	Experiments	31

* For original data, see Appendix C.

Table III

The Chief Interests of 480 High School Girls in Physical Sciences. *

Subject	Topic	Frequency of Mention
I. Astronomy	1. Planets	62
	2. Stars	53
	3. Moon	30
	4. Astronomy	30
	5. Heavenly bodies	12
	6. Sun	11
	7. Solar system	9
II. Chemistry	1. Experiments	89
	2. Analysis	60
	3. Dyeing	30
	4. Acids	30
	5. Metals	22
	6. Foods	22
	7. Soap	21
	8. Equations	20
	9. Oxygen	18
	10. Air	17
III. Geology	1. Rocks	14
	2. Land forms	9
	3. Coal	8
	4. Soil	7
	5. Geology	4
	6. Historical geology	4
IV. Meteorology	1. Weather	16
	2. Climate	9
	3. Winds	6
	4. Clouds	4
	5. Precipitation	4
	6. Atmosphere	4
V. Physical Geography	1. Maps and map-making	9
	2. Climate	3
VI. Physics	1. Electricity	64
	2. Magnetism	41
	3. Sound	35

(Continued on next page)

* For original data, see Appendix D.

Table III (continued)

The Chief Interests of 480 High School Girls in Physical Sciences.

VI. Physics (continued)	4.	Gravity	23
	5.	Heat	23
	6.	Light	19
	7.	Manufacture of ice	14
	8.	Molecules	12
	9.	Mechanics	12
	10.	Internal combustion engines	12
VII. General Interest	1.	Experiments	21

(Table IV follows on next page of thesis)

Table IV

The Most Uninteresting Matters for 536 High School Boys in the Physical Sciences *

Subject	Topic	Frequency of Mention
I. Astronomy	1. Astronomy	13
II. Chemistry	1. Problems	37
	2. Valence	32
	3. Equations	21
	4. Periodic Law	20
	5. Ions	17
	6. Atoms and Molecules	17
	7. Formulas	14
	8. Colloids	12
III. Geology	1. Soils	5
	2. Geology	4
IV. Meteorology	1. Weather and, especially, weather maps	17
	2. Precipitation	4
V. Physical Geography	1. Geography	8
	2. Maps	6
VI. Physics	1. Light and, especially, light rays	72
	2. Sound and, especially musical sound	70
	3. Heat	30
	4. Forces	26
	5. Simple machines	24
	6. Electricity	24

* For original data, see Appendix E.

Table V

The Most Uninteresting Matters for 480 High School Girls in the Physical Sciences *

Subject		Topic	Frequency of Mention
I. Astronomy	1.	Stars	5
	2.	Planets	5
	3.	Astronomy	5
II. Chemistry	1.	Problems	52
	2.	Equations	47
	3.	Formulas	39
	4.	Atoms	37
	5.	Valence	35
	6.	Ions	32
	7.	Molecules	23
	8.	Periodic Law	12
	9.	Water	9
	10.	Recording experiments	9
III. Geology	1.	Soil	6
	2.	Rocks	5
IV. Meteorology	1.	Weather and, especially, weather maps	17
	2.	Winds	8
V. Physical Geography	1.	Maps and map-making	7
	2.	Geography	6
VI. Physics	1.	Electricity	77
	2.	Machines	59
	3.	Light	17
	4.	Heat	14
VII. General Interest	1.	Mathematical elements	9
	2.	Experiments	4

* For original data, see Appendix F.

Table VI shows the numbers of the 1016 high school students who had studied the separate subjects of the physical sciences in junior high schools, or in high school, for at least one semester:

Table VI

Subjects in Physical Sciences Studied by 1016 High School Pupils

Subject	No. of Boys Who Had Studied the Subject	No. of Girls Who Had Studied the Subject	Total No. Who had Studied Subjects
Astronomy	15	14	29
Chemistry	262	289	551
Geography	247	211	458
Geology	20	14	34
Physics	305	83	388
General Science	505	298	803

Interests of Adults

Tables VII-XI present summaries of the interests in the physical sciences of 107 adult teachers and teachers-in-training of Cincinnati, Ohio, neighboring cities, and of the College of Education, University of Cincinnati, Cincinnati, Ohio; of these, 24 were men and 83 were women.

Tables VII to XI follow:

Table VII

Chief Interests in the Physical Sciences of 24 Male Adults *

Topic	Frequency of Mention
1. Electricity and magnetism	15
2. Light	5
3. Chemical analysis	5
4. Motion	4
5. Origin of universe	4
6. Rock formations	4
7. Nature of matter	4
8. Experimentation	3
9. Stars	3
10. Sound	3
11. Space	3
12. Climate	3
13. Minerals	3

* For original data, see Appendix G.

Table VIII

Chief Interests in the Physical Sciences of 83 Female Adults *

Topic	Frequency of Mention
1. Experiments	26
2. Electricity and magnetism	20
3. Light	12
4. Chemical analysis	10
5. Sound	9
6. Planets	8
7. Stars	8
8. Climate	7
9. Gravity	7
10. Atmospheric phenomena	6
11. Geography	6
12. Astronomy	5
13. Geologic periods	4
14. Machines	4
15. Origin of universe	4

* For original data, see Appendix H.

Table IX

Most Uninteresting Matters in the Physical Sciences for 24 Male Adults *

Topic	Frequency of Mention
1. Mathematical elements	17
2. Atmospheric phenomena	5
3. Seasons	3
4. Force	2
5. Light	2
6. Chemical theory	2
7. Terminology	2
8. Manipulation of apparatus	2
9. Mechanisms	2
10. Sound	2

Table X

Most Uninteresting Matters in the Physical Sciences for 83 Female Adults **

Topic	Frequency of Mention
1. Mathematical elements	23
2. Physics	12
3. Astronomy	3
4. Chemistry	3
5. Machines	3

* For original data, see Appendix I.

**For original data, see Appendix J.

Table XI

Subjects in Physical Sciences Studied by 107 Adults *

Subject	No. of Males Who Had Studied the Subjects	No. of Females Who Had Studied the Subjects	Total No. Who Had Studied the Subjects
Astronomy	10	15	25
Chemistry	21	48	69
Geography	20	59	79
Geology	11	21	32
Physics	20	50	70
General Science	16	43	59

Conclusions from the Investigation

The more general conclusions from this investigation of the interests of high school students and adults in the physical sciences are summarized as follows:

(1) In astronomy, the stars and planets are objects of strong interest to high school boys and girls, and to men and women. Astronomy is generally regarded as an interesting subject by high school students and adults.

(2) In chemistry, experimentation and analysis of "unknowns" are highly interesting to boys, girls, and adults. Both boys and girls

* The subject was studied for at least one semester in junior high school, high school, or college.

are interested in dyes. Boys are somewhat more interested in problems in chemistry than are girls; girls find somewhat more interest in chemical equations than do boys. Boys are more interested than girls in chemical theory; girls are more interested than boys in applications of chemistry to the home in such matters as foods and soaps. For most boys and girls, chemical theory and chemical mathematics take first ranks as decidedly uninteresting parts of chemistry.

(3) Rocks, land forms and coal are of interest to boys, girls and male adults, in the field of geology. Girls and women are more interested than boys and men in geologic periods. The study of rocks is easily the leading interest in geology for youth and adults. The interest shown in coal is possibly peculiar to the geographical region of the schools used for this investigation.

(4) Weather, as a topic of study in meteorology, is of interest to about one-half of high school boys and girls; the remainder find it uninteresting, and, particularly, weather maps. Climate is interesting to boys, girls, and adults of both sexes. The study of winds is of more interest to boys than to girls.

(5) In geography, maps and map-making are interesting to about one-half of boys and girls.

(6) Electricity is easily the leading interest of high school boys in physics; approximately 50% of girls find electricity the most interesting subject in physics, and the same percentage find it the most uninteresting. Adults of both sexes report electricity as a leading interest in physics. Interest in magnetism is closely

related to interest in electricity, with the difference that girls find it more interesting than electricity. Boys are about equally divided in interest in sound; generally, interest of boys in musical sound is low. Sound is generally interesting to girls and to adults of both sexes. Light is fairly interesting to adults and to about one-half of high school students of both sexes. Approximately 50% of boys report light as the most uninteresting subject in physics. Interests of boys and girls in physics are very similar. Generally, the interest of boys and girls and of adults in the mathematical elements of physics is lacking, or slight.

(7) The most conspicuous general interest of high school students and adults in the physical sciences is that of experimentation; the most striking lack of interest is in the mathematics of these sciences.

Results from Related Investigations

Astronomy

Krank[3] found 15,448 listings from a count of articles on natural sciences in the Readers' Guide to Periodical Literature, 1922-1924, without allowance for duplications. 1.5% of these articles were on astronomy. An examination of the 1925-1926 issues of 104 magazines revealed 47 articles on astronomy, or less than one article to every two magazines. This investigator also examined ten courses of study and six

[3] Krank, Erma M. Curriculum Study in Astronomy. School Science and Mathematics, Vol. XXVI (1926), p. 952-956.

textbooks in general science. The general conclusion was drawn that astronomy was a subject of little interest to writers of magazines and courses of study.

Krank [4] examined 131 copies of 13 magazines, three of which were scientific, and discovered 100 articles bearing on astronomy, or 65,000 words. Out of a total list of 336 different astronomical terms found, the following considered necessary for intelligent reading of magazine articles on astronomy, appeared ten or more times: (Frequencies of appearance, in parentheses):

Andromeda (29)
astronomer (80)
astronomical (47)
astronomy (27)
atmosphere (57)
axis (11)
calendar (78)
celestial (15)
comet (43)
constellation (13)
corona (11)
diameter (47)
diffuse nebulae (10)
dome (11)
earth (115)
eclipse (53)
equator (22)
fixed star (12)
galactic (12)
galaxy (31)
heavens (32)
horizon (12)
Island universe (10)
Jupiter (27)

latitude (11)
lightyear (20)
longitude (20)
lunar (26)
magnitude (47)
Mars (46)
Mercury (13)
meridian (17)
meteor (40)
Milky Way (35)
moon (127)
nebula (68)
Neptune (16)
new-star (32)
Neva (13)
nucleus (10)
observatory (118)
orbit (31)
Orion (12)
planet (95)
planetary (15)
radiation (28)
rotate (17)
rotation (15)
satellite (14)

Saturn (18)
season (20)
sky (61)
solar (80)
solar system (11)
space (40)
spectrum (38)
spiral nebula (36)
spirals (30)
spot (6)
star (482)
stellar (32)
sun (407)
sunlight (36)
tail (13)
telescope (138)
thermocouple (15)
time (63)
universe (42)
Unranus (17)
variable star (14)
Vega (18)
Venus (17)
world (44)

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4 Krank, Erma M. An Analysis of Magazine Articles on Astronomy. School Science and Mathematics, Vol. XXVIII (1928), p. 51-58.

Major aspects of astronomy developed in these magazine articles, according to Krank, were:

biography (3)
comets (5)
constellations (3)
earth (7)
eclipse (6)
historical (4)
meridians (1)
meteors (4)
Milky Way (1)
nebulae (1)
observatory (1)
planets (8)
satellites (5)
spectra (1)
stars (16)
sun (14)
telescope (8)
time and rotation (8)
universe (4)

Pollock's study [5] of eighth grade childrens' interests, which was based upon 3500 questions asked, gave 975 questions for phases of astronomy, or 28% of the total number.

Curtis' investigation [6] of scientific interests, based upon 3300 questions asked by 687 junior high school pupils, and 3232 questions asked by adults, furnished 879 questions asked by children on subjects in astronomy, or 26% of the total number. Curtis found more interest in astronomy, both for junior high school pupils and adults, than in any other science subject.

The combined investigations of Pollock [7] and Curtis [8] showed that out of 6830 questions asked by pupils of junior high school ages, 1854 questions, or 26%, were about astronomy.

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[5] Pollock, C.A. Childrens' Interests as a Basis of What to Teach in General Science. Educational Research Bulletin, Vol. III (1924), p. 3-6. Bureau of Educational Research, Ohio State University, Columbus, Ohio.

[6] Curtis, F.D. Some Values Derived from Extensive Reading of General Science. Teachers College Contributions to Education, No. 163, 1924. Teachers College, Columbia University, New York City.

[7] Pollock, C.A. loc. cit.

[8] Curtis, F.D. loc. cit.

Krank [9] compared the major aspects of astronomy developed in magazine articles with the results of the investigations of Curtis and Pollock, with the results shown in Table XII:

Table XII

Krank's Study of Magazine Articles on Astronomy Compared with Results of Curtis and Pollock on Childrens' Questions.

Magazine Articles on Major Aspects of Astronomy	Frequency	Childrens' Questions on Astronomy	Frequency
Stars	16	Stars	447
Sun	14	Planets	391
Planets	8	Satellites	211
Time and rotation	8	Sun	187
Telescope	8	Gravity	164
Earth	7	Earth	161
Eclipse	6	Rotation	46
Satellites	5	Sky	37
Comets	5	Northern Lights	32

Curtis [10] counted scientific terms in 630 newspaper articles and found that 13 articles, or 2.1 %, were on phases of astronomy.

From her own investigations, together with those of Curtis [11] and Pollock [12] just described, Krank [13] named the following as essential items for the curriculum in astronomy:

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9 Krank, Erma M. An Analysis of Magazine Articles on Astronomy. School Science and Mathematics, Vol. XXVIII (1928), p. 51-58.

10 Curtis, F.D. loc. cit.

11 Curtis, F.D. loc. cit.

12 Pollock, C.A. loc. cit.

13 Krank, Erma M. loc. cit.

comets	Milky Way	seasons
earth	moon	sky
eclipses	Northern Lights	solar system
gravity	observatory	stars
latitude	planets	sun
Mars	rotation	telescope
meteors		tides

Harap [14] found no place for astronomy in the practical matters of daily living for the average person.

Searle and Ruch [15] investigated files of eleven magazines for a period of ten years [American, Atlantic Current Opinion, Literary Digest, National Geographic, Review of Reviews, Saturday Evening Post (5½ years), Science (5 years), Scientific Monthly (5 years), Scribners, World's Work] for articles which (1) contribute to the scientific background of the reader, (2) are close to interests of children and adults, and (3) develop the scientific attitude of mind. The unit of measurement was the column inch. Outside of the subject matter fields of physics and chemistry, they found that 9.2% of the total of general, or miscellaneous articles, were on astronomy.

Persing [16] and other members of a committee on science teaching in Cleveland schools found that the earth and universe, second only to electricity, were the chief interests of pupils in science in Cleveland.

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[14] Harap, "Economic Life and the Curriculum", The Macmillan Company, 1927, p. 111-132.

[15] Searle, A.H. and Ruch, G.M. Study of Science Articles in Magazines. School Science and Mathematics, Vol. XXVI (1926), p. 389-396.

[16] Persing, Ellis C. Report of Committee of Cleveland Schoolmasters' Club on Science in Greater Cleveland (Ohio). School Science and Mathematics, Vol. XXV (1925), p. 462-474, 600-610.

Craig [17] selected from 4354 childrens' questions on science the fifty-one nouns which appeared most frequently. More than one-third referred to astronomy; these, in order of occurrence, were (Rank according to frequency is given in parentheses):

(2) star	(17.5) Mars	(29) night
(3) sun	(17.5) sky	(32) planet
(5) moon	(24.5) day	(41) summer
(7) earth	(24.5) time	(43) winter
(10) world		(50.5) eclipse

In the same investigation, Craig tabulated the fifty most frequent topics appearing in 6,806 questions asked by 1958 pupils in grades 1-8. One-fifth related to astronomy. In order of frequency these were:

(1) distances in space	(6) sun
(2) origin of earth	(7) stars
(3) the moon	(8) meteors
(4) time	(9) phases of moon
(5) space	(10) tides

The percentage of high school students undertaking astronomy as a separate subjects in public high schools of the United States dropped from 4.79% in 1895 to .07% in 1922. In 1922, however, 18.27% of high school pupils took general science in which is commonly found some astronomy. [18]

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17 Craig, Gerald S. Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School. Teachers College Contributions to Education, No. 276, 1927. Bureau of Publications, Teachers College, Columbia University, New York City.

18 Statistics of Public High Schools, Bulletin No. 7 (1924), p. 46. Bureau of Education, Department of the Interior, Washington, D.C.

Chemistry

Nuser [19] investigated the chemistry in three farmers' journals for the issues of ten years. The order of frequency of occurrence of "principles" was: Change of state, oxidation, neutralization, solutions, chemical changes, definite proportions, ionization, displacement of metals. For occurrence of topics, the order of frequency was: Disinfection, germicides, cleaning agents, chemical preparations, solvents, chemical composition, paints, varnishes, wax, explosives, inflammable materials, acids, drying agents, preservatives, fermentation, bases, emulsions, colloids, water, bleaching, physical properties of chemicals, ore reduction, refrigeration, fire extinguishers, filters, dyes, stains, photography, pasteurization, disintegration, electron theory.

McAlpine [20] found that 2.5% of high school students in Michigan took chemistry in the University of Michigan, and that not over 7.5% of these continued work there in chemistry beyond the first course taken.

Persing [21] reported that Cleveland students found the practical and experimental sides of chemistry most interesting. The following topics in chemistry were regarded as useful and interesting by 70% or more of students:

cement	dyes	glass
combustion	fats	metals
distillation	filtration	salts
	gasoline	soap

[19] Nuser, Arlee. A Study of the Chemistry Found in Agricultural Periodicals. School Science and Mathematics, Vol. XXVII (1927), p. 471.

[20] McAlpine, R.K. Some Aims in Teaching Elementary Chemistry. School Science and Mathematics, Vol. XXVIII (1928), p. 154-163.

[21] Persing, Ellis C. loc. cit.

Pollock [22] found eighth grade pupils interested in gases, solutions and water, particularly.

In chemistry, the percentage of students in public high schools of the United States decreased from 10.10% in 1890 to 7.4% in 1922. [23]

Curtis" investigation [24] of interests in science revealed that 49% of 630 newspaper articles on science dealt with physical sciences, 41.4% with biological science, and the remainder with both. For the scientific terms in these articles, 54.3% were physical and 45.6% were biological in nature. 24.9% of the articles required technical knowledge for understanding when physical, as compared with 5.7% requiring technical knowledge when biological.

For boys and girls together, the most important interests discovered by Curtis [25] in chemistry were, in order, for 687 junior high school pupils:

(1) smoke
(2) air
(3) crude-oil
(4) gases
(5) combustion
(6) history of science

For men and women, the chief interests, in order, for chemistry were for 705 adults: [26]

(1) crude-oil
(2) history of science
(3) air
(4) chemistry
(5) radium
(6) stains
(7) coal

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22 Pollock, C.A. loc. cit.

23 Statistics of Public High Schools. Bulletin No. 7 (1924), p. 46. Bureau of Education, Department of the Interior, Washington, D.D.

24 Curtis, F.D. loc. cit.

25 Curtis, F.D. loc. cit.

26 Curtis, F.D. loc. cit.

The leading interests in chemistry for 305 junior high school boys, 382 junior high school girls, 323 men and 382 women were (not in order): air, crude-oil, history of science. [27]

According to Curtis [28], boys and men were more interested in technical processes and theories than girls and women. Men are more interested than boys in technical processes. Boys, girls and women are more interested in theories than technical processes, and the opposite was true for men. Interests of girls and women were generally more superficial than interests of boys and men. The range of interest for girls was 12.4% greater than for boys; there was a slightly greater range for men than women. Generally, the interests of boys and girls and men and women in chemistry, and other physical sciences, were very similar.

Hopkins [29] found that less than one-fourth as much space was given to chemistry and physics as to biology in newspaper and magazine science articles. Very little space was given to theory in either chemistry or physics. He ranked the sciences in educational value as follows: (1) biology, (2) physics, (3) chemistry, (4) geology, (5) astronomy. Articles referring to chemistry made applications to the shop, farm, home, fertilizers, health, metals, alcohol and "home brew".

The total number of sciences in secondary schools increased from 1908 to 1923, according to Hunter's [30] investigation. Chemistry and

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[27] Curtis, F.D. loc. cit.

[28] Curtis, F.D. loc. cit.

[29] Hopkins, L. Thomas. A Study of Magazine and Newspaper Articles with Relation to Courses in Science for High Schools. School Science and Mathematics, Vol. XXV (1925), p. 793-800.

[30] Hunter, G.S. The Place of Science in the Secondary School. School Review, Vol. XXXIII (1925), p. 370-381, 453-466.

physics courses have increased in number relative to other science courses, and chemistry courses have increased more rapidly than physics courses. Compared with 1908, more hours weekly were given to science in 1923, and more laboratory work was done.

Harap's analysis [31] of man as a consumer showed 850 activities connected with food, clothing, shelter and fuel. 207 of these were related to science and pertained to food, building materials, household articles, household skills, clothing, heating, lighting and fuels. He would have taught in science, relative to foods: mineral salts, food calories, effect of moisture, temperature, light and bacteria on foods, and adulterants. In regard to building materials, the student would learn the properties of woods, brick, stone, tile, hollow tile, terra cotta, lime, glass, cement, concrete, paints, stains, varnish, paint oils, colors, thinners, dryers, floor polish, furniture polish. The student would become acquainted with tool metals, brass, bronze, copper. He would know papers, skins, leathers, cloths, fibres, and their properties, adulteration, and tests for fabrics. Cleaning and polishing preparations, soap, tooth paste, shoe polish, medicated soaps, hard and soft water, and disinfectants would have attention, and he should have adequate knowledge of fuels.

Searle and Ruch [32] have listed the topics in chemistry treated by eleven magazines over a ten-year period. The most important topics found dealt with chemical processes, discoveries, gases, synthesis, atomic weights, analysis and sodium.

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31 Harap, Henry. What Should Science Teaching Accomplish? School Science and Mathematics, Vol. XXVII (1927), p. 60-69.

32 Searle, A. H. and Ruch, G. M. Study of Science Articles in Magazines. School Science and Mathematics, Vol. XXVI (1926), p. 389-396.

Of the fifty-one nouns listed by Craig [33] from childrens' questions on science, only eight deal with plants and animals. Questions on chemical matters were about (in order): water, air, glass, fire and iron. The most frequent general topics were: elements, compounds, mixtures, physical and chemical changes.

Geology and Physical Geography

Among the most frequent questions in science asked by children in Pollock's investigation [34] were questions on the following topics of geology and physical geography: earth, earthquakes, the sea, and volcanoes.

Persing [35] and his committee of science teachers found that the earth was a topic of leading interest and value for science students in Cleveland (Ohio) schools.

In public high schools of the United States the number of students of geology decreased from 5% in 1895 to .16% in 1922; in 1895, 23.89% of students studied physical geography in comparison with 4.28% in 1922. [36]

Earthquakes and volcanoes comprised 2.7% of 630 newspaper articles on science studied by Curtis. [37] The earth, earthquakes,

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[33] Craig, Gerald S. loc. cit.

[34] Pollock, C. A. loc. cit.

[35] Persing, Ellis C. loc. cit.

[36] Statistics of Public High Schools, Bulletin No. 7, 1924, p. 46. Bureau of Education, Department of the Interior, Washington, D.C.

[37] Curtis, F. D. loc. cit.

volcanoes, ocean, geysers, tides, geology, history of science, were, in order, the most important scientific interests of boys and girls in geology and physical geography, as investigated by Curtis.[38] For men and women, in order, the chief interests were: the earth, volcanoes, tides, earthquakes, ocean, history of science, geology, coal, and geysers.

Hopkins [39], on the basis of a study of frequency of science subjects in newspaper and magazine articles, placed geology in fourth place, and preceded by biology, physics and chemistry.

Searle and Ruch [40] found that outside of the fields of physics and chemistry, magazine articles on physiography are more frequent than on any other subject, and that their number constituted 39.3% of other miscellaneous subjects in science.

Craig [41] discovered, on the basis of most frequently appearing nouns, that children were interested in mountains, the rocks, ocean and "ground". The most common larger topic was that of the surface of the earth.

Meteorology

Pollock's [42] study of childrens' interests in science showed that the following topics in meteorology were represented by a

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38 Ibid

39 Hopkins, L. Thomas. loc. cit.

40 Searle, A. H. and Ruch, G. M. loc. cit.

41 Craig, Gerald.S. loc. cit.

42 Pollock, C. A. loc. cit.

comparatively large number of questions from the children: air, clouds, wind, and snow.

Curtis [43] reported 7% of articles on weather and climate from a total of 630 newspaper articles on science. The air, wind, clouds, rain, sky, and snow were reported by Curtis as leading interests of children, and are given in order of interest. In order, the leading interests of adults in meteorology were: air, wind, clouds, rain, and the seasons. [44]

Searle and Ruch [45] discovered that 1.9% of general articles on science in magazines, excluding physics and chemistry, were on meteorology.

Nearly every newspaper of fair size and circulation carries at least a brief weather report.

The clouds, rain, summer, winter, and snow were the most common interests in meteorology expressed by children of the eight grades in Craig's investigation. [46] The weather was the most conspicuous larger topic in the questions.

Mineralogy

Investigations of childrens' and adults' interests in mineralogy are generally included, so far as found at all, under

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[43] Curtis, F. D. loc. cit.

[44] Ibid.

[45] Searle, A. H. and Ruch, G. M. loc. cit.

[46] Craig, Gerald S. loc. cit.

chemistry and geology. Such items as metals, crystals, ores, coal, etc., are found listed under chemistry and geology, for the greater part.

Physics

According to Hunter [47], courses in physics have increased in number relative to other science courses from 1908 to 1923; physics courses have increased less rapidly than chemistry courses.

Hopkins [48] quoted Earl R. Glenn to the effect that the percentage of pupils studying physics in 67% of the largest cities of the United States ranged from .5% in Pittsburg to 17% in Portland, with an average of 8%. Ten years ago the average for the same cities was 14%.

Hopkins [49] found that the theory of physics had little place in newspapers and magazines. He placed physics first in value among the physical sciences on the basis of his investigation of these publications. Articles in this subject treated: physics of the shop, farm and home, the automobile, radio, aeronautics, construction of buildings, ships, tunnels, bridges, highways, railways, electric power, photography, cement, electric signals, steam engines, motion pictures, electric piano, reclamation and drainage, steam turbine, storage battery, "X"rays, strength of materials and water supply.

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[47] Hunter, G. W. loc. cit.

[48] Hopkins, L. Thomas. loc. cit.

[49] Ibid.

The percentage of students studying physics in public high schools was 22.21% in 1890, 14.23% in 1915, and 8.93% in 1922. [50]

Harap [51] recommended the following topics in physics on the basis of an analysis of the practical activities of everyday living: heating, lighting, ventilation, physical properties (as well as chemical) of building materials, household appliances, metals and alloys, papers, leathers, textiles, the automobile, colors, washing machines, furnaces, thermometers, electric lamps, meters and pressure.

Searle and Ruch [52] listed the following topics from their investigation of magazine articles. The number in parentheses following each topic shows the percentage of the total amount, in column inches, found on physics in the periodicals:

(1) light (18.2)
(2) dynamos and machines (16.5)
(3) matter (10.5)
(4) mechanics and work (8.9)
(5) heat (8.2)
(6) mechanics of solids (6.6)
(7) molecules (5.1)
(8) men (5.0)
(9) mechanics of liquids (4.9)
(10) magnetism (3.8)
(11) sound (3.3)
(12) gravity (2.6)
(13) electrostatics (2.4)
(14) energy (1.7)
(15) electric induction (1.2)
(16) electric current (1.1)

In Cleveland schools, science students reported to Persing's committee [53] that electricity, mechanics and light, in order, were most worthwhile to them. Electricity was the most interesting subject in all

[50] Statistics of Public High Schools. Bulletin No. 7, 1924, p. 46. Bureau of Education, Department of the Interior, Washington, D.C.

[51] Harap, Henry. loc. cit.

[52] Searle, A. H. and Ruch, G. M. loc. cit.

[53] Persing, Ellis C. loc. cit.

the science studied.

Pollock's [54] investigation of childrens' interests furnished the following principal topics for physics:

aeroplane	light
air	lightning
clouds	machinery
earth	radio
electricity	rotation
gases	sound
gravity	water-supply
heat	

23% of the questions asked by 3500 children were on the subjects: electricity, lightning, radio, telephone and compass.

Curtis [55] found that 49% of newspaper articles were on physical science subjects, compared with 41.4% for the biological sciences. 54.3% of the scientific terms found in the newspaper articles were physical, and 45.6% biological. 24.9% of the physical science articles demanded technical knowledge, compared with 5.7% for the biological. The most common subjects in physics for the newspaper articles were (Figures in parentheses show percentage of total number of articles.):

radio (8.7)	heat (2.9)
aeronautics (6.3)	light (2.5)
automobile (3.7)	sound (.3)

Curtis [56] concluded that boys, girls, men and women were much more interested in physical than in biological science. Boys and men

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[54] Pollock, C. A. loc. cit.
[55] Curtis, F. D. loc. cit.
[56] Ibid.

were more interested in technical processes representing applications of physics; men were more interested than boys in these processes. Boys, girls and women were more interested in theory than in technical processes. For men, the leading interest was in technical processes. Interest for girls was more superficial in physics, the girls showing a wider range of interests than boys.

For boys and girls together, the most important interests in physics were, in order:

(1) electricity	(7) light	(12) sound
(2) earth	(8) Aurora Borealis	(13) eclipses
(3) gravity	(9) thunder	(14) gases
(4) radio	(10) geysers	(15) history of science
(5) lightning	(11) tides	(16) rainbow
(6) air		(17) snow

For men and women together:

(1) radio	(6) history of science	(10) lightning
(2) electricity	(7) air	(11) automobile
(3) earth	(8) sound	(12) radium
(4) tides	(9) light	(13) geysers
(5) gravity		(14) thunder

For boys, girls, men and women, the chief interests in physics (not in order) were:

air	gravity	radio
earth	history of science	sound
electricity	light	thunder
geysers	lightning	tides

Herriott [57] made an investigation of everyday activities

[57] Herriott, M.E. Life Activities and the Physics Curriculum. School Science and Mathematics, Vol. XXIV (1924), p. 631-634. One influence of Out-of-School Activities in Determining the High School Physics Curriculum. School Science and Mathematics, Vol. XXVII (1927), p. 56-60.

involving physics (rather than expressed interests) for boys and girls, and adults. The order of importance for boys and girls was:

Boys	Girls
(1) magnetism and electricity	(1) sound
(2) invisible radiations	(2) light
(3) mechanics	(3) heat
(4) light	(4) mechanics
(5) sound	(5) magnetism and electricity
	(6) invisible radiations

Earl R. Glenn [58] learned that 4% of boys and 6% of girls in Indiana schools studied physics, from reports of science teachers. 60.7% of the teachers reported that the average textbook was too difficult for girls; 71.9% said that average textbook was sufficiently easy for boys. According to some of these teachers, the following topics in physics should be dropped or reduced in amount:

(1) specific gravity
(2) sound
(3) properties of matter
(4) hard problems
(5) technical subjects
(6) accelerated motion
(7) static electricity
(8) problems in electricity and heat
(9) parts of electricity

Some teachers favored including or lengthening the following topics:

(1) historical physics
(2) practical matters
(3) strength of materials
(4) "X"rays
(5) battery
(6) mechanics
(7) elementary design
(8) weather maps
(9) physics of the farm

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[58] Glenn, Earl R. High School Physics in the State of Indiana. School Science and Mathematics, Vol. XIII (1913), p. 483-491.

Greater attention to practical matters was the change mainly advocated.

Watson [59] made an investigation of the content of high school physics with respect to its "social" value by having 659 parents of pupils taking physics in Kansas check items as (1) worthwhile, (2) of doubtful value, and (3) of no value. Such items as transformers, the telescope, the microscope, aeroplane, high tension electric lines, dynamos, rheostats, etc., were considered of no value by these Kansans! Items of value furnished are more worthy of consideration; Kansas parents of physics students were interested in having their boys and girls master the following matters which are not usually stressed in physics:

automobile tires	ice-cream freezer
automobile brakes	kerosene lamp
automobile radiator	kitchen range
ball bearings	oil stove
clock pendulum	repair of pump valve
clock regulation	roller bearings
cream separator	sewing machine
door lock	soldering
fever thermometer	water traps
fountain pen	windmill
heating stove	window-shade rollers
hoze nozzle	vacuum sweepers

Heiss, Ritchie and Powers [60] counted the articles on natural science listed in a magazine index for 1922-1924. Of 15,448 listings,

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59 Watson, C. H. A Critical Study of the Content of High School Physics with Respect to Its Social Value. School Review, Vol. XXXIV (1926), p. 688-697.

60 Heiss, E. D., Ritchie, Earland and Powers, S.R., Curriculum Study in Natural Science. Electricity and Magnetism. School Science and Mathematics, Vol. XXVIII (1928), p. 368-375.

6350 dealt with the physical sciences. 1699 articles were on radio, 67 on magnetism, and 533 other articles were on something else about electricity. The investigators made an additional study of 123 magazine articles on science, five popular textbooks in general science, and ten city and state courses of study for materials on electricity and magnetism. They finally compared their results with Harap's [61] analysis of consumer needs, Curtis' newspaper study of scientific terms [62], and the results of the investigations of Curtis [63] and Pollock [64] on childrens' interests as revealed by their questions on science. With the exception of Harap's analysis [65], all of the investigations named, including the one here reported, emphasized strikingly pupil and adult interests in the subjects of electricity and magnetism.

Heiss, Ritchie and Powers [66] also listed the terms of electricity and magnetism encountered in reading magazine articles, and the major ideas of electricity and magnetism found in the periodicals. On the basis of all of the investigations which they were able to find, and their own, they finally prepared the outline of a course of study in

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61 Harap, Henry. loc. cit.

62 Curtis, F. D. loc. cit.

63 Curtis, F. D. loc. cit.

64 Pollock, C. A. loc. cit.

65 Harap, Henry. loc. cit.

66 Heiss, E. D., Ritchie, Earland and Powers, S. R. loc.cit.

electricity and magnetism. This course consists, presumably, of the essentials of electricity and magnetism for ordinary, educated people. (All items on electricity and magnetism in the tentative organization of materials, Chapter VI, have been checked against the work of Heiss, Ritchie and Powers [67].)

From a list of nouns in childrens' questions, Craig [68] found that they were most interested in the following items of physics (in order of interest):

(1) electricity
(2) color
(3) lightning
(4) radio
(5) gas
(6) clocks
(7) thunder
(8) Northern Lights
(9) airplane
(10) light

The most common topics of interest were, in order:

(1) atmosphere
(2) electricity
(3) physical properties of matter
(4) practical appliances
(5) gravitation
(6) change of state of water
(7) light
(8) machines
(9) sound
(10) lightning
(11) flotation
(12) three states of matter
(13) thunder
(14) power

Conclusions from the Related Investigations

(1) Popular interest in astronomy as measured by magazine and newspaper articles is only fair; the more direct measure by means of questions asked in science showed that astronomy is easily the most

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[67] Heiss, E. D., Ritchie, Earland and Powers, S.R. loc.cit.

[68] Craig, Gerald S. loc. cit.

interesting science to junior high school pupils and adults. Astronomy was a leading interest of high school pupils in Cleveland. Using interest as the criterion, the essentials of the high school course of study in astronomy are well established by the investigations made.

(2) Chemistry is of interest to the farmer. Chemistry is not a popular subject in high school or college. The weight of evidence is in favor of stronger interest on the part of readers of newspapers for the physical sciences rather than the biological. Readers of newspaper articles on chemistry require considerable technical knowledge for understanding. The practical and experimental matters are interesting to high school students in chemistry. Boys and girls of junior high school age are more interested in the theoretical than the technical; the technical interest is characteristic of males, and increases with age. Boys of high school age should find greater interest in the traditional chemistry course because of stronger interests than girls in the technical processes and theoretical aspects of the subject. Chemistry is closely related to the utilitarian activities of the everyday life of the citizen. Interests of pupils and adults in chemistry are much alike.

(3) Using the frequency of appearance of articles as the gauge, interest of readers of newspapers in matters of geology and physical geography is only fair; interest of magazine readers is apparently considerably stronger. Interests of junior high school pupils and of high school students in both subjects are strong. Interests of children and adults in the subjects are much alike.

(4) Interests in meteorological subjects are keen for both pupils and adults, and are strikingly similar.

(5) Physics, as taught in the usual high school, is not interesting to many high school students; it is less interesting to girls than to boys. Boys and girls, however, are probably more interested in physical than biological phenomena; the same is true for adults. High school physics may be taught so that it connects closely with daily activities of the average man or woman. Readers of newspapers and magazines, presumably, are strongly interested in articles on physics; considerable technical knowledge is required to read these articles understandingly. In high school physics, boys are more interested in technical processes than girls; both boys and girls are more interested in the theory of physics than in technical processes; and, probably, boys are more interested than girls in both theory and technical matters. The interests of boys, girls, men and women in physics are much alike; electricity, in its various phases, is the chief interest of all ages in physics; it is apparently the chief scientific interest of mankind today.

(6) Although some investigations have reached contrary conclusions[69], the weight of evidence is that interest in the physical sciences is generally greater than in the biological sciences.[70]

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[69] Downing, E. R. Childrens' Interests in Nature Materials. Nature Study Review, Vol. VIII (1912), p. 334-338.

[70] Curtis, F. D. A Study of the Scientific Interests of Dwellers in Small Towns and in the Country. Peabody Journal of Education, Vol. V (1927-1928), p. 23-34.

Summary of Conclusions

An investigation of the interests in the physical sciences of 1016 high school students, of about equal numbers of both sexes, from many different high schools, from several states, and from both urban and rural environments, together with results of similar and related investigations, established the following principal conclusions:

1. Astronomy, considering whole subjects, is generally the physical science which is most interesting to pupils in junior and senior high schools.

2. The experimental and practical phases of chemistry are most interesting to high school pupils; the least interesting parts of chemistry to these pupils are theory, technical matters and the mathematical elements. Traditional high school chemistry is not a popular subject.

3. Geology is a subject of fair interest to high school students. Study of the rocks, land forms and minerals are most interesting to these students.

4. In meteorology, there is found strong interest which is focused largely upon the topic of climate.

5. Physics, as customarily taught, is not of particular interest to high school students, but is more interesting to boys than to girls. Electricity is decidedly the most interesting topic in the physical sciences for boys and girls; the interest of the boys exceeds

that of the girls, however. Interest in mathematical, technical and theoretical physics is weak.

6. Interest in experimentation is the most striking general interest for boys and girls in the physical sciences; the most conspicuous lack of interest is in the mathematical elements of these sciences.[71]

7. Interest in physical phenomena is probably generally greater than interest in the biological sciences, if allowance is made for lack of interest due to traditional content and methods in the high school physical sciences.

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[71] Teaching Science as a "Way of Life". Bulletin of High Points in the Work of the Schools of New York City, Vol. X (October, 1928), No. 8, p. 68, 72-73.

Chapter III

THE PSYCHOLOGY OF INTEREST APPLIED TO SCIENCE

Use of the Novel

Man is naturally attentive to the novel in his environment.[1] "The attitude of childhood is naïve, wondering, experimental; the world of man and nature is new. Right methods of education preserve and perfect this attitude, and thereby short-circuit for the individual the slow progress of the race, eliminating the waste that comes from inert routine." [2]

"Novel things to look at or novel sounds to hear . . . . will always divert the attention from abstract conceptions . . . . Living things, moving things, ... that have a dramatic quality, - these are the objects natively interesting to childhood. . . . . Begin with the line of his native interests. . . . ." [3]

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[1] Thorndike, "Educational Psychology", Teachers College, Columbia University, New York, 1913-1914, vol. 1, p. 46-47, 141.

[2] Dewey, "How We Think", D. C. Heath and Company, Boston, 1910, p. 156.

[3] James, "Talks to Teachers on Psychology: And to Students on Some of Life's Ideals", Henry Holt and Company, New York, 1901, p. 92-96.

The teacher, course of study, textbook and divisions of the subject in science should all begin [4] with the new, strange, unusual and foreign; they should all lead to the old, familiar, usual, and to the immediate environment. [5]

The Laws of Effect, Readiness and Mental Set

By the Law of Effect, interest in science furthers learning; indifference and dissatisfaction hinder learning. [6] It is important, then, that original and acquired interests should be considered (1) in the selection of subject matter of science in advance of the time of learning, and (2) during the learning process itself. When these matters are properly attended to, the learning of science is more rapid; the results of learning are more permanent; there is more of concomitant learning. [7]

By the Principles of Readiness [8] and the Law of Mental Set [9], it is evident that when a pupil approaches scientific subject matter by the route of an acquired or original interest, his potentialities for learning are thereby increased; both temporary and permanent attitudes favorable to learning science are present, or may be generated with comparative ease.

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[4] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 331-332.

[5] Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 516-517.

[6] Thorndike, E.L. op. cit., vol. 2, p. 4.

[7] Thorndike, E.L. op. cit., vol. 3, p. 127-128.

[8] Thorndike, E.L. op. cit., vol. 1, p. 128.

[9] Thorndike, E.L. op. cit., vol. 2, p. 24-26.

These attitudes operate as selective agents in future activities having to do with science, and they are more or less permanently connected with other learned elements of science, such as scientific facts or skills. The temporary attitudes favorable to learning are valuable for their immediately possible effects in promoting learning then and there; the more persistent attitudes, "sets" and "interests" are powerfully compelling influences in the future career of the individual possessor. The latter, if favorable, will shunt the youth or adult toward further experiences of a scientific nature in the activities of everyday life; if unfavorable, they will instigate equally potent avoiding reactions toward matters scientific. Attitudes in science persist long after facts and principles have become vague, or have been forgotten.

What is learned in science, in any case, is never subject matter but particular reactions.[10] The particular reactions described by such terms as "mental sets", "attitudes" and "interests" need to be taken into account not only in the preliminary responses of the learner as he approaches the science, or science topic, but also in the intermediate and consummatory stages of the learning process. The reactions of the learner described by such terms as "previous knowledge", "apperceptive mass", "learning the unknown in terms of the known", "skills", "facts", "ideas", etc., are much more likely to be considered at all stages of the learning process than the more subtle reactions just described. The

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[10] Gates, "Psychology for Students of Education", The Macmillan Company, 1923, p. 207-208, 266-269.

latter are very significant despite their subtlety; the correlation of the obvious with the valuable remains to be demonstrated for the learning of anything. The feeling or affective state called interest is the prime force in the generation and modification of "sets" and attitudes; in order to take these subtler reactions into account in a science course of study, the interests of the learner must be taken into account.

The Principles of Intensity and Recency

The greater the intensity of satisfaction resulting from interest in science the greater the effect upon learning, by the Principle of Intensity (of effect). [11] Other things being equal, high school students will master the subject of electricity better than any other topic of science taught in the schools.

According to the Principle of Recency [12], the more closely (in time) the satisfaction of the student is connected with the learning activity, the greater the effect on learning. Learning of facts in science in situations which postpone, or deny altogether, the satisfactions which normally arise from fruitful learning experiences is wasteful; under such conditions learning is feeble and paltry.

Relation of Interest to Ability

The employment of the psychology of interest in building courses of study in science, and in science teaching, is strongly supported by the

[11] Gates, Arthur I. op. cit., p. 234.
[12] Ibid.

high correlation between the interests of elementary, high school and college students in school subjects and their abilities in these subjects. Thorndike's elaborate investigations [13] gave r = .9 for this relation, and this coefficient is, as he says, "one of the closest of any that are known". [14] Pupils' interests in school subjects are almost a perfect guide as to what they can do successfully. The inability of science students to become interested in the complexities and abstractions of mathematical elements of the sciences is matched almost exactly by their inability to master these perplexities; and is almost certainly indicative that much of the mathematics of the physical sciences of the high school is unsuited to the levels of maturity and experience of the students there. "The school can help pupils to master science only when it arranges its courses in this field in conformity with their abilities", according to Judd. [15]

Superficial Interests

The interests of younger students in natural phenomena are, of course in most cases, interests which cannot be regarded as strictly scientific. [16] The peculiar interest possessed by the scientist, which is a part of the scientific attitude of mind, has been long developing in the race; it is acquired only with difficulty, and very

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[13] Thorndike, E.L. Early Interests: Their Permanence and Relation to Abilities. School and Society, Vol. V (1917), p. 178-179.

[14] Thorndike, E.L. The Permanence of Interests and Their Relation to Abilities. Popular Science Monthly, Vol.LXXXI (1912),p.449-456.

[15] Judd, "Psychology of Secondary Education", Ginn and Company, Boston, 1927, p. 327.

[16] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304, 313.

slowly, by the immature mind. The superficiality of the extensive interests of younger pupils toward scientific phenomena may, in individual instances, appear to really operate against truly scientific interests. The chief values of the earlier interests in science of youthful minds, even though relatively superficial, lie in their inherent possibilities for initiating learning under highly favorable circumstances, not only for the science as a whole but, also, for the phases of the subject as it develops.

Cultivation of Interests

> Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. . . . . Associate the new with the old in some natural and telling way, so that the interest, being slid along from point to point, suffuses the entire system of objects of thought.[17]

It is fairly obvious that interest in science is subject to cultivation, per se, and without regard to other factors of learning; it is not quite as obvious, at least in course of study preparation and teaching of science, that attitudes and indifference, or feelings of dislike, are also subject to cultivation. ". . . . We are interested in what we have learned to be interested in, enjoy what we have learned to enjoy, and dislike what we have learned to dislike".[18]

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[17] James, "Talks to Teachers on Psychology: And to Students on Some of Life's Ideals", Henry Holt and Company, New York, 1901, p.94-96.

[18] Woodworth, "Dynamic Psychology", Columbia University Press, New York, 1918, p. 77.

It is probably true that the physical sciences are now very generally taught in American high schools by use of subject matter and methods which not only fail to cultivate strong interests in the pupils taking these subjects, but in a real sense, and on a large scale, lead to the production of dissatisfactions, and even aversions.[19]

Interest and Cultural Values

For the attainment of the cultural values of science, the importance of interest can hardly be overestimated. Snedden has said that the subject matter of general science is relatively unimportant; the important matters are: a keenly interested teacher, vitally interested pupils, and ample facilities for rich experiences. Instead of exclusively insisting upon interpretation of the environment of the pupil, ". . . . the Aurora Borealis may be more significant to curiosity and cultural interests, ... tigers in India than sparrows on the back lot; and the big trees of California than the elms of the local highway".[20]

For the development of cultural values in the physical sciences, knowledge does not need to be practical, technical, or highly exact. Essential knowledge and techniques need not be acquired "once for all"; vocational aims in the physical sciences defeat the cultural

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[19] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304, 337.

[20] Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 516-517.

purpose for those who make no vocational use, later on, of their acquisitions. "Cultural ends are best served by developing and extending appreciations, broad interpretations and insights, persisting interests".[21]

Interest in Problem Solving

Interest in problem-solving is a most valuable interest, not only for science, but for all subjects. It is repeatedly claimed for science that it has peculiar powers for the cultivation of this interest. The history of pure science demonstrates the value of the interest in problem-solving for the progress of science itself; the story of the applications of pure science to the needs of man is proof of the value of interest in problem-solving in the service of science to mankind. How is the interest in solving problems to be cultivated?

First of all, the science student must be confronted with problematic situations which are not too difficult for success. "It is a general principle of human activity that we are interested in overcoming difficulties and interested, on the other hand, in what we can do successfully - in a word, we are interested in successfully overcoming difficulties".[22]

The high school student should be led to find his own problematic situations - to discover problems. Textbooks, courses of study

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[21] Snedden, David. op. cit., p. 520-521.

[22] Woodworth, R. S. op. cit., p. 202.

laboratory experiments and methods which continually give the impression to the student that the aim in learning a science is the learning of the conclusions of problems which have already been solved, work decidedly against the cultivation of an interest in problem-solving. The student is led to believe that the last word has been said, that all has been found out; instead he should be "led to see that every object about him has characteristics which ought to arouse his inquiring mind to a scientific study".[23]

In order to arouse interest in problem-solving, the personal and human elements should be stressed in relation to things. Children are not so much interested in the natural environment for its own sake, but rather in its human relations.[24]

The concrete and specific problem, rather than the abstract and general, is probably more hopeful for success in arousing an interest in problem-solving with immature minds. The historical approach to the problem, which describes the previous experiences of man with its solution, may be productive of interest.[25]

Interest and Effort

The relation of interest to effort, activity and growth in the

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[23] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 330-332.

[24] Dewey, "Interest and Effort in Education", Houghton Mifflin Company, Boston, 1913, p. 85-87.

[25] Judd, Charles H. op. cit., p. 337.

sciences, has been best described by Dewey.[26] The efforts of the child flow freely, whole-heartedly, and in the direction of the pupil's own growth, in a situation where genuine interests exist. The child has identified himself with the activity. Interest is felt as the pupil finds self-expression and self-development in the activity; ". . . . the teacher must select activities with reference to the child's interests, powers and capacities."[27]

Use of Interest in Course of Study Construction

The seeming conflict between childrens' interests and adults' needs in education has long received attention from educators.[28] Probably the best settlement is reached by the principle that adult needs determine primarily matters of permanent value, while childrens' interests determine the order of presentation and the organization of learning materials at the various stages of child development.[29]

Interest and Psychological Organization

Likewise, the related problem of the psychological organization of subject matter versus the logical[30] is best solved by viewing the whole

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[26] Dewey, John. op. cit., p. 7, 15, 21, 41, 43.

[27] Suzzalo, Introduction to Dewey's "Interest and Effort in Education", Houghton Mifflin Company, Boston, 1913, p. IX.

[28] National Society for Study of Education. Twenty-sixth Yearbook (1926), p. 13.

[29] Charters, "Curriculum Construction", The Macmillan Company, New York, 1923, p. 102.

[30] Kilpatrick, "Foundations of Method", The Macmillan Company, New York, 1925, p. 302, 309-310.

process of education; the psychological organization is then evidently the beginner's steps in this process, while the logical organization shows more clearly the results of the process. Reliance upon interest in science is a fundamental principle of the psychological order, but the final attainment of logical organization in science does not exclude interest. [31]

Conclusions

By way of conclusions, the psychology of interest as applied to science may be summarized as follows:

(1) The approach to a science, or divisions of a science, is most productive of interest when made by way of novel phenomena.

(2) Interest in science increases the rapidity, permanence and amount of learning.

(3) Interest provides for desirable concomitant learning in such matters as "sets", or attitudes toward science.

(4) Within limits, strong interests lead to better activities for learning than do mild or weak interests.

(5) Interest should be closely associated with the learning activity in time.

(6) Pupils' interests are an excellent guide to their abilities in science.

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[31] Betts, "Social Principles of Education", Charles Scribner's Sons, New York, 1912, p. 281-283.

(7) Earlier, superficial interests are valuable in initiating learning as the subject changes.

(8) Indifference toward science, or dislike for it, may be cultivated, as well as interest and liking.

(9) The cultural values of science depend mainly upon appreciations secured through interest.

(10) By right methods, interest in problem-solving may be learned by pupils studying science.

(11) The pupil is genuinely interested in science when he has identified himself with its activities.

(12) The psychological order of arrangement of subject-matter depends largely upon consideration of pupils' interests.

(13) The psychology of interest is an important criterion for the arrangement of subject matter in science in advance of learning.

Chapter IV

THE AIMS OF SECONDARY SCHOOL SCIENCE

An Investigation of the General Aims of High School Science

An inquiry [a] was directed to colleges and departments of education in state universities, other universities and colleges, and to state departments of education in order to secure a list of names of outstanding instructors in science and science education, and also in order to gain touch with recent developments in high school courses of study in the physical sciences. Later, a request [b] to furnish a statement of the general aims of science in the high school was sent to one hundred of these most competent instructors in the physical sciences and science education of universities, colleges, teachers' colleges, normal schools and high schools. Twenty-five signed statements were received from different sections of the United States; of these, thirteen [c] were furnished by university and college professors in the physical sciences, nine [d] by high school teachers, and three [e] by instructors in science education in universities and colleges.

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[a] See Appendix K.
[b] See Appendix L.
[c] See Appendix M.
[d] See Appendix N.
[e] See Appendix O.

In Table XIII appears the list of general aims furnished by the twenty-five outstanding instructors:

Table XIII

A List of General Aims for High School Physical Science

No.	Statement of Aim	Frequency of Mention	Rank
1.	Training in the ability to think scientifically	9	1
2.	Interest in and appreciation of the physical environment	8	2
3.	Understanding of the physical environment	7	3
4.	Understanding and appreciation of the value of science to human welfare	6	4.5
5.	Cultivation of the scientific attitude of mind	6	4.5
6.	Understanding of the applications of science to everyday life	5	7
7.	Educational and vocational guidance	5	7
8.	Appreciation of law and system in nature	5	7
9.	The scientific habit of mind	4	10.5
10.	Habits of accurate observation of nature	4	10.5
11.	Appreciation of scientific method	4	10.5
12.	The ability to use scientific methods	4	10.5
13.	Manual and technical skills	3	15.5
14.	Liberal education	3	15.5
15.	Understanding of fundamentals of science	3	15.5
16.	Arousal of scientific curiosity	3	15.5
17.	Ability to read science intelligently	3	15.5
18.	Applications of science to health	3	15.5
19.	Appreciation of the great scientists	2	20.5
20.	Ability to use scientific appliances	2	20.5
21.	Habits of accuracy	2	20.5
22.	Love of science	2	20.5
23.	Grasp of technical terminology	1	30.5
24.	Knowledge of occupational worth	1	30.5
25.	Knowledge of conventional value	1	30.5
26.	Intellectual honesty	1	30.5
27.	Open-mindedness	1	30.5

(continued on next page)

Table XIII (continued)

A List of General Aims for High School Physical Science

No.	Statement of Aim	Frequency of Mention	Rank
28.	Problem-solving attitude	1	30.5
29.	Understanding of matter and energy	1	30.5
30.	Scientific ways of expression	1	30.5
31.	Originality	1	30.5
32.	Appreciation of the simplicity of science	1	30.5
33.	The principle of conservation	1	30.5
34.	Interrelations and interdependence of science	1	30.5
35.	Preparation for college science	1	30.5
36.	Leisure time activities	1	30.5
37.	Appreciation of the unity of science	1	30.5
38.	Science for intelligent conversation	1	30.5

The list of general aims presented in Table XIII is combined and summarized in Table XIV:

Table XIV

Summary of General Aims for High School Physical Science

No.	Statement of Aim	Items of Table XIII Combined
1.	Development of the ability to think scientifically	1, 5, 9, 10, 11, 12, 16, 21, 26, 27, 28, 30, 31 Total, 13 items
2.	Knowledge of the physical environment	3, 8, 14, 15, 25, 29, 32, 33, 34, 35, 37 Total, 11 items
3.	Understanding and skill in applications of science to everyday life	4, 6, 7, 13, 18, 20, 24 Total, 7 items
4.	Appreciation of and interest in the physical environment	2, 17, 19, 22, 23, 36, 38 Total, 7 items

The list of general aims for the high school physical sciences of Table XV was collected from science courses of study, syllabi, textbooks, bulletins, pamphlets, magazine articles, other publications of educators and scientists, personal letters from scientists and educators, and the responses to an inquiry sent to outstanding science teachers and educators in the various states. The names of the last were secured through the cooperation of departments of education of colleges, universities and the states.

With a minimum change of statement, elimination of only most obvious duplications, and with no attempt to remedy overlapping, the aims were placed in random order in the check-list as shown in Table XV. This check-list was sent to ten professors of science education, and to ten high school supervisors of science; the list was also checked by the members of a graduate class in high school science teaching, and by other competent graduate students of science education in the College of Education, University of Cincinnati.

(For Table XV, see following page of thesis)

Table XV

General Aims for the High School Sciences

Please check ( ) the essentially important aims for high school sciences.

1. To give a unified view of science.
2. To acquire knowledge of scientific facts, principles and theory.
3. To learn the applications of science in industry, the home, on the farm, in everyday life, in communication, travel, transportation, heating, lighting, etc.
4. To understand common natural phenomena.
5. To provide a fund of interesting information.
6. To introduce the student to nature.
7. To furnish a basis for intelligent and interesting conversation.
8. To encourage acquisition of knowledge by first-hand contact with things and individual investigation.
9. To develop scientific and philosophic insight.
10. To impart the cultural values of science.
11. To develop the concept of conservation.
12. To show the relations of man and nature.
13. To gain knowledge of and interests in the great scientists and their contributions.
14. To learn where scientific information may be had.
15. To develop the concept of law and order in nature.
16. To develop the concept of cause and effect.
17. To enable the individual to understand scientific articles in newspapers, magazines, etc.
18. To furnish the means of control of nature.
19. To acquire technique and skill in laboratory experimentation.
20. To acquire habits of order, accuracy and speed.
21. To establish the habit of reading science.
22. To establish the scientific habit of mind.
23. To establish good habits of study.
24. To gain facility in problem solving.
25. To learn the need of cooperation in social groups.
26. To train in thinking.
27. To develop ability in the expression of ideas about science in a scientific way.
28. To stimulate the imagination.
29. To stimulate the pupil to more direct and purposeful activities.
30. To learn the simpler quantitative relationships and receive training in representing quantitative facts.
31. To develop the powers of observation.
32. To impart the moral values of science.
33. Good citizenship.
34. To cultivate the aesthetic values.

(continued on next page)

Table XV (continued)

General Aims for the High School Sciences

35. To develop religious attitudes.
36. To develop the attitude of facing reality squarely.
37. To instill the attitudes and ideals of scientists.
38. To free from tradition, prejudice and superstition.
39. To arouse intellectual curiosity about nature.
40. To stimulate investigation, originality and invention.
41. To prove scientific law, principles and constants experimentally.
42. By experimentation, to develop more adequate ideas, concepts and generalizations about scientific matters.
43. By experimentation, to discover scientific law for one's self.
44. To give training to use of the scientific method.
45. To show the value of science in prediction.
46. To add to enjoyment of the natural environment.
47. To provide activities for leisure time.
48. To learn to appreciate the value of masterful performance.
49. To learn to appreciate the value of quantitative thinking.
50. To captivate interests in order to increase the holding power of the school.
51. To develop appreciation of the value of research.
52. To give help in choice of vocation.
53. To awaken scientific interests and abilities.
54. To give direct preparation for vocations.
55. To prepare for more specialized study of science in college.
56. Health.
57. To supply material for teaching the fundamental processes of reading, writing, mathematics and composition.

Note: The list of "aims" above has been gathered from courses of study in science, science textbooks and the writings of educaters. Please add any essential aim which, in your opinion, should be stated.

Five signed replies were received from professors of science education [1], and six from supervisors of sciences [2]; two replies were received unsigned from these groups. Twenty-four graduate students in science education checked the list. A total of thirty-five competent people cooperated in this investigation.

Table XVI gives a summary of the general aims of high school science teaching which are considered to be essentially important by five university and college professors of science education, most of whom have national reputations in their speciality. Table XVI follows.

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1 (1) Curtis, Francis D., Professor of the Teaching of Biological and General Science, University of Michigan.
(2) Hill, L. B., Professor of Education (specialist in science education), West Virginia University.
(3) Morris, Meister, Professor of Science Education, College of the City of New York.
(4) Palmer, E. R., Professor of Science Education, Cornell University.
(5) Webb, H. A., Professor of Chemistry, George Peabody College for Teachers.

2 (1) Avery, Lewis B., Director of Science, Oakland, California.
(2) Edwards, Paul G., Supervisor of Science, Chicago, Illinois.
(3) Fowlkes, Floyd E., Director of Science, Richmond, Virginia.
(4) McMachin, J. G., Supervisor of Science, Spokane, Washington.
(5) Redenbaugh, W. M., Supervisor of Science, Seattle, Washington.
(6) Wildman, Edward E., Director of Science Education, Philadelphia, Pennsylvania.

Table XVI

Summary of Aims of High School Science Selected by University Specialists

No. of Aim (See Table XV)	Frequency of Checking	Rank	No. of Aim (See Table XV)	Frequency of Checking	Rank
3	4	2	43	2	23
8	4	2	44	2	23
39	4	2	47	2	23
4	3	8	51	2	23
12	3	8	2	1	43.5
17	3	8	6	1	43.5
21	3	8	7	1	43.5
31	3	8	9	1	43.5
46	3	8	10	1	43.5
52	3	8	18	1	43.5
53	3	8	19	1	43.5
56	3	8	20	1	43.5
1	2	23	24	1	43.5
5	2	23	25	1	43.5
11	2	23	29	1	43.5
13	2	23	30	1	43.5
14	2	23	32	1	43.5
15	2	23	34	1	43.5
16	2	23	38	1	43.5
22	2	23	41	1	43.5
23	2	23	45	1	43.5
26	2	23	49	1	43.5
27	2	23	50	1	43.5
28	2	23	55	1	43.5
33	2	23	35	0	55.5
36	2	23	48	0	55.5
37	2	23	54	0	55.5
40	2	23	57	0	55.5
42	2	23			

Table XVII presents the work of six prominent supervisors of science in checking aims for high school science:

Table XVII

Summary of Aims of High School Science Selected by Supervisors

No. of Aim (See Table XV)	Frequency of Checking	Rank	No. of Aim (See Table XV)	Frequency of Checking	Rank
3	6	1	43	2	28.5
2	5	3	48	2	28.5
31	5	3	51	2	28.5
46	5	3	53	2	28.5
4	4	7	56	2	28.5
8	4	7	5	1	41
22	4	7	6	1	41
38	4	7	17	1	41
52	4	7	21	1	41
9	3	16	23	1	41
13	3	16	24	1	41
14	3	16	26	1	41
15	3	16	28	1	41
16	3	16	33	1	41
18	3	16	41	1	41
19	3	16	50	1	41
20	3	16	55	1	41
36	3	16	57	1	41
39	3	16	7	0	52.5
40	3	16	27	0	52.5
44	3	16	30	0	52.5
47	3	16	32	0	52.5
1	2	28.5	34	0	52.5
10	2	28.5	35	0	52.5
11	2	28.5	37	0	52.5
12	2	28.5	45	0	52.5
25	2	28.5	49	0	52.5
29	2	28.5	54	0	52.5
42	2	28.5			

In Table XVIII appears the general aims for science in the high school according to the combined judgments of the five university specialists in secondary school science and the six city supervisors of science education.

Table XVIII

General Aims of High School Science According to Specialists & Supervisors

No. of Aim (See Table XV)	Frequency of Checking	Rank	No. of Aim (See Table XV)	Frequency of Checking	Rank
3	10	1	42	4	27
8	8	3	43	4	27
31	8	3	51	4	27
46	8	3	5	3	36.5
4	7	6	10	3	36.5
39	7	6	23	3	36.5
52	7	6	25	3	36.5
2	6	8.5	26	3	36.5
22	6	8.5	28	3	36.5
12	5	15.5	29	3	36.5
13	5	15.5	33	3	36.5
14	5	15.5	6	2	44.5
15	5	15.5	24	2	44.5
16	5	15.5	27	2	44.5
36	5	15.5	37	2	44.5
38	5	15.5	41	2	44.5
40	5	15.5	48	2	44.5
44	5	15.5	50	2	44.5
47	5	15.5	55	2	44.5
53	5	15.5	7	1	52
56	5	15.5	30	1	52
1	4	27	32	1	52
9	4	27	34	1	52
11	4	27	45	1	52
17	4	27	49	1	52
18	4	27	57	1	52
19	4	27	35	0	56.5
20	4	27	54	0	56.5
21	4	27			

Table XIX gives the general aims of science for the high school according to the combined selections of five university specialists in high school science, six prominent city supervisors of science education, and twenty-four other competent judges, most of whom were graduate students in science education. A total of thirty-five judges checked the list of aims of Table XV, with the following results:

Table XIX

General Aims of High School Science According to Thirty-five Experts

No. of Aim (See Table XV)	Frequency of Checking	Rank	No. of Aim (See Table XV)	Frequency of Checking	Rank
3	34	1	39	10	30
56	24	2	5	9	32
4	23	3	9	9	32
8	22	4.5	17	9	32
47	22	4.5	11	8	35.5
31	21	6.5	21	8	35.5
38	21	6.5	23	8	35.5
2	20	8	51	8	35.5
15	19	9.5	24	7	38.5
46	19	9.5	27	7	38.5
16	17	11.5	18	6	42
53	17	11.5	28	6	42
52	16	14	32	6	42
12	16	14	43	6	42
33	16	14	50	6	42
1	15	16.5	30	5	45.5
22	15	16.5	34	5	45.5
44	14	19.5	7	4	49.5
6	14	19.5	10	4	49.5
13	14	19.5	25	4	49.5
42	14	19.5	41	4	49.5
14	13	23	45	4	49.5
19	13	23	48	4	49.5
36	13	23	37	3	54
20	12	26	49	3	54
26	12	26	57	3	54
29	12	26	35	1	55
40	11	28.5	54	0	56
55	11	28.5			

In Table XX is shown a summary and classification of the items of Table XIX:

Table XX

Summary of General Aims of High School Science According to Thirty-five Experts

No.	Statement of General Aim	Items of Table XIX by No. and Ranks			
		No.	Rank	No.	Rank
1	Development of the ability to think scientifically	31	6.5	9	32
		38	6.5	23	35.5
		22	16.5	24	38.5
		42	19.5	27	38.5
		44	19.5	43	42
		36	23	28	42
		19	23	30	45.5
		20	26	41	49.5
		26	26	48	49.5
		29	26	37	54
		40	28.5	49	54
		39	30		
			Total Number of Items, 23		
2	Knowledge of the physical environment	4	3	6	19.5
		8	4.5	14	23
		2	8	55	28.5
		15	9.5	11	35.5
		16	11.5	10	49.5
		1	16.5	57	54
			Total Number of Items, 12		
3	Understanding & skill in the applications of science to everyday living	3	1	32	42
		56	2	25	49.5
		12	14	45	49.5
		52	14	35	55
		33	14	54	56
		18	42		
			Total Number of Items, 11		

(continued on next page)

Table XX (continued)

Summary of General Aims of High School Science According to Thirty-five Experts

No.	Statement of General Aim	Items of Table XIX by No. and Ranks			
		No.	Rank	No.	Rank
4	Appreciation of and interest in the physical environment	47	4.5	21	35.5
		46	9.5	51	35.5
		53	11.5	50	42
		13	19.5	34	45.5
		17	32	7	49.5
		5	32		
			Total Number of Items, 11		

Conclusions from the Investigation of the General Aims of Science

The conclusions from this investigation of the general aims of science teaching in the high school by means of the judgments of sixty specialists in the field are summarized as follows:

1. The variability in the judgment of these competent specialists concerning the general aims of high school science is extremely wide.

2. If very comprehensive statements of the general aims of secondary school science are formulated, the numerous limited statements of aims may be combined and included under four principal heads:

(1) Development of the ability to think scientifically

(2) Knowledge of the physical environment

(3) Understanding and skill in the applications of science to everyday life

(4) Appreciation of and interest in the physical environment.

3. The order of importance of these four comprehensive aims is approximately the order of statement above. In the thinking of experts, the first receives decidedly the most consideration; the second has a fair lead over the third and fourth, which occupy about the same position.

4. The teaching of high school science to give direct preparation for the vocations has exactly zero merit according to the ratings of sixty experts cooperating in this investigation.

5. That high school science should be taught so as to prepare for more specialized study of science in college receives little consideration from the majority of the sixty specialists assisting in the investigation; the tendency to depart from this traditional aim of high school science was very noticeable in the cases of city supervisors of science and professors of science education.

Other Investigations of the Aims of Secondary School Science

Good[3] listed the general aims of high school science from

[3] Good, Carter V. Mathematics and Science Curricula in Junior and Senior High Schools. School Science and Mathematics, Vol. XXVII (1927), p. 863-869.

an examination of state and city courses of study. The most frequent statements of aims appear in Table XXI:

Table XXI

Good's List of General Aims of Science from Courses of Study

No.	Statement of Aim	Frequency
1.	To help interpret the environment	12
2.	Citizenship	8
3.	To provide a fund of interesting information	7
4.	Better acquaintance with science of the environment	6
5.	Development of accurate habits of observation and expression	6
6.	To awaken scientific interest and ability	6
7.	To acquire techniques of experimentation	6
8.	Training in scientific method	6
9.	Understanding of scientific phenomena and its applications.	5
10.	To instill scientific attitudes	5
11.	To reveal the scientific vocations	5
12.	Health	4
13.	To provide hobbies for leisure time	4
14.	To furnish general knowledge to beginners	4
15.	Vocational training	4
16.	Worthy home membership	4

Aims which appeared with a frequency less than four are omitted from Table XXI, not only because of low frequency, but because of overlapping and a variety in the wording of identical ideas.

Harap [4] listed four major aims for science: (1) interpretation

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4. Harap, Henry. What Should Science Teaching Accomplish? School Science and Mathematics, Vol. XXVII (1927), p. 60-69, or

Harap, "Economic Life and the Curriculum", The Macmillan Company, New York, 1927, p. 111-132.

of scientific matters in normal reading of the average person, (2) increase in one's enjoyment of the environment, (3) satisfaction of curiosity about natural phenomena, (4) and utilization of science in improvement of everyday life. Harap believed the last to be most important; in his analysis of man's activities as a consumer he relied upon it entirely in relation to science, although it is reasonable that the first and second above have to do with consumer needs. He showed that about one-fourth of man's daily utilitarian activities were based upon or related to science.

Persing [5], with a committee of science teachers in Cleveland, tried to formulate general aims for science in Cleveland schools. A wide disagreement as to these objectives resulted. Among the aims stressed were (not arranged in order):

(1) Training in thinking

(2) Understanding of the environment

(3) Ability to read intelligently scientific materials

(4) Habits of persistence

(5) Habits of accuracy

(6) Open-mindedness

(7) Honesty

(8) Comprehension of natural laws which combat superstition

(9) Understanding of the applications of science to civic problems

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[5] Persing, Ellis G. Cleveland Schoolmasters' Club: Committee Report on Science in Greater Cleveland (Ohio), E.C. Persing, Chairman. School Science and Mathematics, Vol. XXV (1925), p. 462-474.

With special reference to chemistry, McAlpine [6], from a study of conditions in Michigan schools, concluded that training for college science was not a proper major aim of secondary school science.

A committee [7] of the Central Association of Science and Mathematics Teachers presented the following aims for high school science (random order):

(1) Knowledge for improving daily life

(2) Citizenship

(3) Help in vocational choice

(4) Scientific methods

(5) Enjoyment of life

In a report [8] made to the Council of the American Association for the Advancement of Science, December, 1927, by the Special Committee on the Place of Science in Education, the following general aims were emphasized (not in order of importance):

(1) Character

(2) Culture

(3) Elimination of tradition, predjudice, superstition

(4) Scientific method

(5) The scientific attitude

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[6] McAlpine, R.K. Some Aims in Teaching Elementary Chemistry. School Science and Mathematics, Vol. XXVIII (1928), p. 154-163.

[7] Preliminary Report on a Unified Science Course, Otis W. Caldwell, Chairman; School Science and Mathematics, Vol. XIV (1914), p.166-168.

[8] The Place of Science in Education. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

The committee on science [9] of the Commission on the Reorganization of Secondary Education described the contributions of science to main objectives of education, and also listed five "specific values of science study":

(1) Development of interests, habits and abilities

(2) Teaching methods of solving problems

(3) Stimulation of direct and purposeful activities

(4) Valuable information

(5) Cultural and aesthetic values

The science committee [10] of the Secondary School Curriculum Project of West Virginia, assisted by competent science instructors of the state, listed the following general aims for junior and senior high school science (no particular order):

(1) Knowledge of natural science factors of the environment

(2) Understanding of everyday scientific happenings and their applications

(3) Control of natural science factors of everyday life and ability to solve scientific problems

(4) Intelligent interest in science subjects of everyday life

(5) Habits of reading science intelligently

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[9] Reorganization of Science in Secondary Schools. Bulletin, 1920, No. 26, p. 14-15. Bureau of Education, Department of the Interior, Washington, D. C.

[10] Organization, Administration and Course of Study for Junior and Senior High Schools, 1927, p. 9-10, 186. Department of Education, State of West Virginia, Charleston, West Virginia.

Pieper and Beauchamp [11], with junior high school general science particularly in mind, listed the following general objectives for science instruction (no particular order):

(1) Acquisition of knowledge of phenomena necessary to the citizen in solution of everyday problems

(2) Discovery and development of attitudes, habits, abilities and skills essential in problem solving

(3) Development of and growth in attitudes toward, appreciation of, and adaptations to the environment

(4) Development of interests for leisure time and guidance

Bobbitt [12], as one result of his cooperative plan of curriculum making in Los Angeles and Chicago, gave the following objectives for science (order unimportant):

(1) Health

(2) Unspecialized practical activities

(3) Civic affairs

(4) Appreciation

(5) Reading

(6) Leisure time hobbies

(7) Scientific method

(8) Understanding of environment

(9) Specialized activities

(10) Vision to see nature

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[11] Pieper and Beauchamp, "Teacher's Guidebook for Everyday Problems in Science", Scott, Foresman and Company, Chicago, 1927, p. 2-3.

[12] Bobbitt, "How to Make a Curriculum", Houghton Mifflin Company, Boston, 1924, p. 141-143.

The Committee on the Objectives of Secondary Education [13], Commission on the Curriculum, Department of Superintendence of the National Education Association of the United States, has formulated four principal objectives for secondary education; the second of these is a statement of the functions of science, particularly, in the secondary school:

> To promote the development of an understanding and an appreciation of the world of nature.

Howe [14] had eighty teachers rank the aims of general science, with results as shown in Table XXII:

(For Table XXII, see following page)

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[13] Objectives of Secondary Education. Sixth Yearbook, 1928, Department of Superintendence, National Education Association of the United States, Washington, D. C.

[14] Howe, Clayton M. What 80 Teachers Think as to the Aims and Subject Matter of General Science. General Science Quarterly, Vol. II (1918), p. 445-458.

Table XXII

Average Rank of Aims in General Science According to Howe

No.	Statement of Aim	Average of Ranks Assigned
1.	Understanding, appreciation, and control of everyday environment	1.8
2.	Appreciation of the applications of science in industrial and social life	3.5
3.	A fund of valuable information about nature and the sciences	3.7
4.	Training in the use of scientific method in solving problems	4.5
5.	Preparation and foundation for later study of the special sciences	5.0
6.	Interest and movtivation in school work to prevent elimination	5.1
7.	A vocational survey of the sciences to guide and inspire life work	5.4
8.	Appreciation of the unity and beauty of science, and of its master minds	6.3
9.	Training in cold, scientific thinking involving self-elimination	7.6

Conclusions from Related Investigations

1. A wide variety of general aims exists for science in the secondary school.

2. Several aims listed in the investigations reported here apply directly to education in general and not to science in particular.

3. When differences in wording, viewpoint and emphasis are taken into account, the wide variability of general aims for high school science is greatly reduced.

Summary of Conclusions

It is very evident that the narrow propaedutic values of high school sciences for college and the vocations were not prominent in these investigations; the aims of science in the high school, on the contrary, pointed the course of study and methods toward the larger principles of individual development and social participation. In its most extreme form, this tendency, in the cases of certain investigations, has led to no differentiation between the general aims of secondary education and of secondary school science.

An apparent multiplicity of general aims for high school science results in confusion which can be clarified by a consideration of the larger issues involved, interpretation of viewpoints, appreciation of the intended emphasis, and elimination of superficial differences due to variations in phraseology.

The major goals of science instruction in the high school were, in reality, comparatively few, from these investigations; the numerous aims revolved about four fundamental thought centers:

(1) The influence of science education upon the thinking of the individual

(2) Knowledge of nature

(3) Applications of science to everyday life

(4) Enjoyment of the natural environment

Chapter V

THE PHILOSOPHY OF SECONDARY SCHOOL SCIENCE

Science in Modern Life

The modern world, particularly in the Occident, is largely distinguished from mediaeval and ancient civilizations by the development of modern science [1] and its applications to the lives of men. [2]

> The citizen uses modern science, both its subject matter and its method, at each turn of his day's work: he uses it in his problem of food selection, in his transportation, his communication and his recreation. If he is a thinking citizen, he is ambitious to profit by what he understands as scientific facts, principles and occurrences, if unthinking, he reaps the benefits of his fellows' applications. [3]

> Man's life is bound up in the processes of nature; his career, for success or defeat, depends upon the way in which nature enters it. [4]

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[1] Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1926, p. 8-9.

[2] Russell, "Science", in "Whither Mankind", Charles A. Beard, Editor, Longmans, Green and Company, New York, 1928, p. 70.

[3] The Place of Science in Education. Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, Nashville, December, 1927. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

[4] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 267.

> Under present conditions, all activity, to be successful, has to be directed somewhere and somehow by the scientific expert - it is a case of applied science.[5]

The average person is mainly interested in science as a consumer, and not as a producer. "In his understanding of street construction, or of a telephone system, or the problem of water supply, the citizen is in the first instance a consumer. . . . ."[6] Harap's analysis[7] of man as a consumer revealed 850 activities connected with food, shelter, clothing and fuel; of these, 257 activities were based upon science.

As a consumer, man is not only concerned with science in its narrowly utilitarian relationships with the more commonplace activities of daily life, but in its cultural aspects as well. Referring to science, Snedden described its cultural phases in terms of "appreciations, broad interpretations and insights, persisting interests".[8] Dewey has emphasized the importance of significant meanings and interests for cultural outcomes.[9] ". . . . Any subject is cultural in the degree in which it is apprehended in its widest possible range of meanings". Whenever a person responds, because of

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[5] Dewey, "The School and Society", The University of Chicago Press, Chicago, 1915, rev. ed., p. 21.

[6] Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 397.

[7] Harap, "Economic Life and the Curriculum", The Macmillan Company, 1927, p. 111-132.

[8] Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 520-521.

[9] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 334-336, 283-284.

aroused interest, to some element of science, that element has already justified itself culturally in his life, and that by the fact that he did respond; no further justification is necessary.

A small minority of individuals in the modern world are assiduously engaged with science as producers. Of these, two groups are conspicuous - the one consisting of highly trained research workers in the field of pure science; the other equally highly trained technicians in the work of producing scientific goods. Both of these groups stand at the pinnacle of extreme specialization in modern civilization; in the past history of men there has been nothing similar; they are peculiarly typical of a complex social order. Through the facilities provided by enormous wealth and advanced educational institutions, a few are persuaded to give themselves to a training period which occupies more than a third of their lives in order that they may possibly, during the remaining years, advance a little the frontiers of knowledge and control of man and nature.

Recent changes in ways of living have been very rapid, due to applications of science. New discoveries and inventions are made, literally, every day. As far as one can see ahead, it appears to be true that the importance of science to immediately following generations will not be less than it is to the present. [10]

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[10] Kilpatrick, W. H. op. cit., p. 39-40.

> It cannot be too often nor too emphatically repeated that society is passing through the greatest transition of recorded history, by all odds and far away! The recent shift from muscle power to steam, electricity, and gasoline is producing a new order of things. A new democratic, applied-science, machinofacture, supercivilization is in the process of becoming. The magnitude of the adjustment is almost impossible to realize. [11]

Man has gained signal control over the physical environment through science, but scientific control of the social environment is still in the earliest stages. [12]

> What does seem clear is we cannot stand still with the measure of science that exists in western civilization. We must either have more science, in particular, biological science, or gradually become incapable of wielding the science we already have. . . . . It is essential that we should learn to use the machine without worshipping it. [13]

The general use of science, its methods and thinking, by the mass of the population of this country, is still narrowly limited. The average citizen of the United States realizes, superficially, that science has touched his life in recent, new ways; he is impressed and gratified by the external proofs and services of science in his environment; but he has not taken science into his own mind, and made it a part of his everyday living. [14] "It has taken endless ages to create

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[11] Finney, "A Sociological Philosophy of Education", The Macmillan Company, New York, 1928, p. 279.

[12] Kilpatrick, W. H. op. cit., p. 45-49.

[13] Russell, Bertrand. op. cit., p. 81-82.

[14] Slosson, Edwin E. Action and Reaction in Spreading Science. School and Society, Vol. XXIII (1926), p. 223-230.

in men the courage that will accept the truth simply because it is the truth". [15]

> The mass of our population is still the victim of tradition, predjudice and superstition and unmindful if not unconscious of the methods of working which scientists have developed and employed in their researches to reveal truth. [16]

> A recent writer said that probably not one hundred people in the United States really understand why the "movies seem to move" - in the profounder psychological sense, that is. [17]

Coal was prevented by law from being sold in Philadelphia in 1803. "Lew" Wallace was defeated for Congress in Indiana in 1844 because he had voted for a telegraph line between Baltimore and Washington, thus, as his opponent said, "encouraging some crank who has a fool idea he can send messages by lightning". In 1926 a steamship regularly crossed the Atlantic ocean carrying two enormous, useless smokestacks because people refused to patronize a vessel which did not have the familiar signs of engine power, although the vessel was equipped with the most modern Diesel engines. [18] A large part of the world has not benefited even to the degree of the United States by understanding and control of physical nature. "Persons who have traveled much about the earth report

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[15] Coolidge, Calvin. Address before the American Association for the Advancement of Science, 1925.

[16] Report of the Special Committee on the Place of Science in Education. loc. cit.

[17] Snedden, David. op. cit., p. 513.

[18] Slosson, Edwin E. loc. cit.

that probably the majority of the human race would still vote that the earth is not round". [19]

The fact that science is not readily accessible to the average man hinders its proper functions in modern life. [20] Much of it is buried in the pages of scientific journals, monographs and books which are not widely circulated among the general population. It is technical, abstract and professional in character, oftentimes, even when it does reach the reading public, or the learning pupils. It should be rewritten and related to man's life, needs and desires [21]; in this form it becomes "a story, not merely of inanimate nature, but of the great drama of human development". [22]

Some Characteristics of Science

It has long been customary to consider two divisions of science; pure science which has no purpose outside of itself, and applied science which is concerned with prediction and control of environmental factors. As a matter of fact, there is probably no element of truth which is completely insulated from man's experience. [23] It is common

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[19] Report of the Special Committee on the Place of Science in Education. loc. cit.

[20] Robinson, "The Humanizing of Knowledge", George H. Doran Company, New York, 1923, p. 30-91.

[21] Dewey, "Interest and Effort in Education", Houghton Mifflin Company, Boston, 1913, p. 85-87.

[22] Bode, "Modern Educational Theories", The Macmillan Company, New York, 1922, p. 213.

[23] Judd, "Psychology of Secondary Education", Ginn and Company, Boston, 1927, p. 339.

knowledge that the "pure science" of today becomes the "applied science" of tomorrow, and an instrument for man's welfare. It is rather that some phases of science, at a given time, more adequately fill human needs than other phases; the difference is one of degree and not of kind. [24]

By its very nature science is a whole because truth itself is a whole. "The truth is ultimately a unitary thing; all fits together in one great pattern, like the parts of a puzzle map". [25]

> The entire science of physics is none too much to interpret adequately to us what is involved in some simple demand of the child for explanation of some causal change that has attracted his attention. [26]

Another two-fold division of science is traditional natural science, and social science. Adults make sharp distinctions between their relations to things and their relations to other people; children, however, are interested in things only in so far as the things do have human relationships. [27] A natural science, such as physics, is in reality inextricably interwoven with life; the relations are there although

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[24] Betts, "Social Principles of Education", Charles Scribner's Sons, New York, 1912, p. 149.

[25] Betts, George H. op. cit., p. 151.

[26] Dewey, "The Child and the Curriculum", The University of Chicago Press, Chicago, 1911, p. 22.

[27] Dewey, "Interest and Effort in Education", Houghton Mifflin Company, Boston, 1913, p. 85-87.

they may be obscured or concealed. [28] The interplay of social and natural science is prevented, for example, by the "transplanting into our educational system the technical divisions of scientific research". [29] "Whatever natural science may be for the specialist, for educational purposes it is knowledge of the conditions of human action". [30]

In one sense a scientific subject is a mirror held up to furnish a single view of nature; with a sufficiently large and perfect reflector all of nature would be revealed in its workings. In the "massive phenomena which confront, or are reported to, learners from their environment", [31] the unity of science is apparent. Dewey's statement [32] that the unity of all science is found in geography may be changed, with equal truth, to read that the unity of all science is found in the natural environment.

Then science is coming gradually to be regarded, not as knowledge but as " . . . . a manner of life, a way of behaving . . . ." [33] This new viewpoint is based upon the so-called instrumental theory of

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[28] Bode, Boyd H. op. cit., p. 15.

[29] Robinson, J. H. op. cit., p. 82.

[30] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 267.

[31] Snedden, David. op. cit., p. 115.

[32] Dewey, "School and Society", University of Chicago Press, Chicago, 1915, rev. ed., p. 16.

[33] Russell, Bertrand. op. cit., p. 65-66.

knowledge. "In the Instrumental Theory, there is not a single state of mind which consists of knowing a truth - there is a way of acting, a manner of handling the environment, which is appropriate, and whose appropriateness constitutes what alone can be called knowledge as the philosophers (James and Dewey) understand it."[34] Thus, science functions as a whole in a mode of life. As a way of living, science is not limited to the intellectual responses only; it includes all forms of responses - affective[35], volitional and habitual[36] - as well as cognitive.

The psychology of learning supports this instrumental theory of knowledge and science. What we learn in any case are particular reactions, and the reactions learned are the reactions that we actually make.[37] Psychologically, subject matter, such as physics or chemistry, is never learned; what is learned consists of particular reactions which one makes to the physical and chemical situations presented to him through subject matter. "Nothing is for practical purposes learned until it is made over into one's actual way of behaving".[38]

The unity of science is further established by consideration of the methods which are common to the special sciences. These are, essentially, experimentation and mathematical techniques.[39] These

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[34] Russell, Bertrand. op. cit., p. 72.

[35] Betts, G. H. op. cit., p. 155-162.

[36] Russell, Bertrand. op. cit., p. 65-66.

[37] Gates, "Psychology for Students of Education", The Macmillan Company, New York, 1923, p. 266-267.

[38] Kilpatrick, "Foundations of Method", The Macmillan Company, New York, 1925, p. 308.

[39] Gates, A. I. op. cit., p. 9.

methods are one of the greatest of the contributions of science to the modern world [40]; they were acquired in the face of enormous difficulties, and very late in the life of the race. [41] "The scientist is preeminently an investigator. . . . .He undertakes to prove all things that lie within his field and holds fast only to that which he can prove". [42]

> These men (the scientists) crave a meticulous precision of observation, measurement and statement quite alien to other teachers of men. They exhibit an almost shocking insensibility to the cherished motives of belief. They do not ask whether what is sought is either right or wrong, beautiful or ugly, useful or futile, comforting or distressing. They only ask whether what is found out is something really happening.[43]

Thus, science is ultimately a mode of attack upon problematic situations, rather than a body of knowledge. The versatile investigator is able to adapt himself readily to either physics or psychology; the method of science is the common denominator of all the special sciences.

Finally, the attitudes of scientists furnish an additional unifying concept which is basic to all of the special fields of science. Best investigated by Curtis [44], the "scientific attitude of mind" has been resolved into five major attitudes:

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[40] Betts, G. H. op. cit., p. 107-108.

[41] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 313.

[42] Betts, G. H. loc. cit.

[43] Robinson, J. H. op. cit., p. 29-30.

[44] Curtis, "A Determination of the Scientific Attitudes", Francis D. Curtis, University of Michigan, Ann Arbor, Michigan. Reprinted from the Journal of Chemical Education, Vol. III, No.8, (August, 1926).

(1) Conviction of basic cause and effect relations

(2) Sensitive curiosity about reasons for happenings, together with definite ideals for observation, collection of data, use of data, and search for explanations

(3) Habits of delayed response, tentative formulation of generalizations, and reflection

(4) Habits of weighing evidence

(5) Tolerance and open-mindedness

It is evident from Curtis' analysis that the scientific attitude consists principally, and psychologically, of certain habits of thought. There has been a general failure to distinguish the scientific attitude from scientific method which represents the employment of external and objective techniques in highly specialized ways. In his everyday activities, the average individual may reasonably be expected to use only a smattering of the techniques of the professional research worker, but, with reasonable effort, he may acquire the attitudes of science which are highly significant for intelligent living.

Toward natural phenomena, the attitude of the child is far from scientific; it is superficial, wayward and unguarded rather than penetrating, persistent and cautious.[45] The roots, however, of the scientific attitude of mind are buried in the naive and wondering contemplation of nature and man which characterizes childhood.[46]

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[45] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304.

[46] Dewey, "How We Think", D. C. Heath and Company, Boston, 1910, p. 156.

Most persons fail to meet most of the common problematic situations of living equipped with the scientific attitude of mind.[47] This situation demands a change. The future of democratic civilizations depends, in large degree, upon wide extension and firm establishment of scientific habits of thought. The opponents of the scientific attitude, superstition, credulity and bigotry, are foremost and powerful chieftains among the enemies of enlightment and progress. The first problem of science education in a democratic social order is the problem of teaching the scientific attitudes of mind.[48]

Thus, it is seen that a leading characteristic of science is its unity. It is found in the breaking down of the division of pure and applied science in the service of science to man's needs; in the wholeness of truth itself, which knows no partitions; in the reciprocal relations of man and inanimate nature, which destroy the artificial barrier between natural and social science; in the oneness of the universe of nature, which is not plotted, fenced or walled; in the philosophy of (scientific) knowledge as a way of living, which is supported by the principles of learning of modern psychology; in the methods of science which are common to all of its special fields of research; and, finally, in the attitudes of science which consist essentially of habits of thinking which are capable of being acquired in

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[47] Kilpatrick, W. H. Subject Matter and the Educative Process, Journal of Educational Method. Vol. II (1923), p. 374.

[48] Twiss, "A Textbook in the Principles of Science Teaching", The Macmillan Company, New York, 1917, p. 83.

any division of science study and transferred to other divisions, or to life. In the highest sense, the greatest synthesis of science consists of the union of human experience with scientific thinking; this is the synthesis of all knowledge. [49]

Problems of Science Teaching in the Secondary School

One of the mooted questions of science teaching in the high school is the problem of adult needs versus child needs in science instruction. A conservative viewpoint on this issue, and one which partially irons out the conflict, is desirable. [50] For both adults and adolescents, activities, interests and needs should be considered; those of adult life are guides for the more permanent values, while those of adolescence largely determine the order of presentation and the arrangement of subject matter. [51]

These principles do not imply that all adult needs are necessarily to be met in high school science instruction, however remote they may be from activities of adolescents; on the other hand, they do not imply that all interests of high school youth are to be considered, regardless of whether they are socially desirable, or whether

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[49] Judd, "Psychology of Secondary Education", Ginn and Company, Boston, 1927, p. 339.

[50] National Society for the Study of Education. Twenty-sixth Yearbook, Part II (1926), p. 13. Public School Publishing Company, Bloomington, Illinois.

[51] Charters, "Curriculum Construction", The Macmillan Company, New York, 1923, p. 102.

whether they may be directed toward socially desirable outcomes.[52] It must be recognized, too, that all permanent values, by the principle of adult needs, cannot be foreseen in a rapidly changing society. At least in part, science teaching in the high school should prepare youth to meet the varying conditions of a mobile environment where new values will be constantly derived, new methods, aims, and ideals substituted for the old, tried ways.[53]

In existing high school science courses sufficient attention has not been paid to pupil needs, interests and activities.

> The school can help pupils to master science only when it arranges its courses in the field in conformity with their abilities. Whenever the school fails in the teaching of science, the failure is due to a lack of recognition on the part of the teacher of the abstract and difficult character of the thinking which science demands of its pupils.[54]

Hurd[55] investigated 244 written articles in science by 110 authorities during the years 1900-1926; of these, 64.3 per cent stated that the principal need of high school science was well chosen subject matter suited to the needs of pupils. The relative popularity of general science and modern biology, compared with liking for physics and chemistry, is largely due to the fact that the former have been reorganized in accord with pupils' needs, interests and abilities.

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[52] National Society for the Study of Education. op. cit., p. 13.

[53] Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1926, p. 85-86.

[54] Judd, "Psychology of Secondary Education", Ginn and Company, Boston, 1927, p. 327.

[55] Hurd, A. W. Present Inadequacies and Suggested Remedies in the Teaching of High School Science. School Science and Mathematics, Vol. XXVIII (1928), p. 637-639.

The investigations of the prevailing aims of secondary school science showed little emphasis upon direct preparation for college, or college science. (See Chapter IV.) The platform of a great educator and a great scientist on this matter is as follows: [56]

> Whatever is properly a high school subject is to that extent proper and effective preparation for university study; that the high-school curriculum is primarily a subject for determination by secondary-school men; and that, aside from insisting on high standards, the university should avoid all intent and appearance of dictation. . . .

In spite of the common theoretical viewpoint which favors freedom of high school science from university influences, in practice, the situation is well to the contrary. Physics and chemistry, particularly, are well grounded subjects for college entrance; one or both are likely to be required for admission to more conservative institutions, either by acceptance of high school credits in the subjects, or by examinations set by college authorities. High school science teachers often follow the outlines of their own elementary college courses in the subjects. Many high school textbooks in science have been prepared by college professors. In cooperative course of study revision the university professors of science may, and frequently do, exert strong influence. The total effect of these factors has been a strong downward pressure from the higher institutions toward the formulation

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[56] Jordan, David Starr. Fourth Annual Report of the President, Leland Standford Junior University. Trustees' Series No. 15, (1907), p. 88.

and maintenance of high school science courses according to university desires and ideals; this influence has been especially strong fot the physical sciences of the junior and senior years of high school.

In smaller high schools, particularly, the resultant situation has been far from desirable, not only for the science subjects, but for the entire curriculum of the four-year high school. In New York state[57], for example, 90 per cent of the smaller high schools offer only college preparatory courses in spite of the fact that 95 per cent of high school freshmen do not go on to college there. The smaller the high school the lower is the percentage of graduates who will enter college.[58] "Regardless of this, the typical small high school spends a major portion of its energies offering college preparatory subjects of the traditional sort".[59]

There is wide inconsistency in the positions of higher institutions which directly or indirectly influence the teaching of secondary school science, if the large duplication of high school science work by the colleges is considered.[60] Koos analyzed the contents of chemistry textbooks and courses of study of twenty-six high schools and

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[57] Coxe, W.W. Educational Needs of Pupils in Small High Schools. National Education Association of the United States. Department of Superintendence, Official Report, Boston (1928), p. 169.

[58] The Development of the High School Curriculum. National Education Association of the United States. Department of Superintendence, Sixth Yearbook (1928), p. 171.

[59] Problems of Articulation in the Small High School. National Education Association of the United States. Department of Superintendence, Seventh Yearbook (1929), p. 169.

[60] Ruediger, W. C. Curricular Gaps. School and Society, Vol.XXVII (1927), p. 274-278.

forty-one higher institutions in the central states, with the conclusion that their courses were "in reality much alike".[61] If, in the future, universities are to continue to offer what has heretofore been taught in high school science courses, it would appear reasonable that they should encourage the high school in its effort to reorganize their courses more in accord with adolescent needs. Such duplication is indefensible, and is prima facie evidence of strong college domination of high school physics and chemistry.

The vocational aims in high school science instruction also receives scant attention, in theory, from those who formulate current statements of aims (See Chapter IV); but, in practice, there is considerable emphasis toward certain vocational activities, and perhaps without full realization of the fact that these activities are essentially vocational in nature. The vocations involved are those of the research worker in pure science and the technical expert in applied science. These activities are not so easily understood as being vocations as the activities, for example, of the plumber, carpenter, or automobile mechanic; but both are vocations in the economic sense of being activities in which individuals are seriously engaged in production of goods. The training of these two groups of experts should preferably be left to specialized and higher institutions[62], except, perhaps, for the largest high schools where

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[61] Koos, L. V. Overlapping in High School and College. Journal of Educational Research, Vol. XI, No. 5 (May, 1925), p. 322-336.

[62] Betts, G. H. op. cit., p. 109.

very specialized subjects may be taught, in addition to more regular offerings. Snedden [63] has most emphatically stated that the vocational aim will defeat the cultural values of high school science for most boys and girls. Science education for the majority of high school youth should be aimed toward ". . . . intelligent use and consumption of products" [64], rather than for production.

In relation to physical science, as well as to other high school subjects, there is some reliance upon the aim of teaching the elements, or fundamentals of the subjects. This may result in an attempt to inculcate knowledge strongly partaking of the professional character of the work of the physicist, chemist, or geologist; on the other hand, it may mean an effort to teach highly abstract knowledge and, hence, facts and principles almost entirely removed from meaningful human experiences. [65]

According to Snedden, ". . . . there is, for up-to-date pedagogy, too much of pious faith about this purpose of teaching the 'elements' of any subject. We do not any longer attempt to teach the English language through alphabets and grammar. Too many introductory texts in chemistry seem still to present the subject as penmanship was presented in the days of 'pot-hooks'". [66]

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[63] Snedden, David. op. cit., p. 520-524.
[64] Douglass, A. A. op. cit., p. 397.
[65] Robinson, J. H. op. cit., p. 91.
[66] Snedden, David. op. cit., p. 520-524.

"As it is, interest is stifled through insistence that the pupil master 'the fundamental principles' upon which the science is based, or that they gain a 'clear idea of the underlying principles' of the science and a 'definite knowledge of its most important facts'."[67]

The aim of the development of the individual through science, as sometimes given, plainly sounds of faculty psychology, and especially when applied to thinking, appreciation, etc. Development does not mean getting something for nothing out of the mind. "It is a development of experience and into experience that is really wanted".[68] To be developed, the abilities of the mind must function on something; the amount and rate of development depend, in large part, upon the stimulation afforded by the activities of the subject being learned.

The perfection of organization of science has required many centuries for attainment, and represents the cumulative effects of many of the most competent minds. In this form it is beyond the capacities of average high school students, or even of average adults. "It is only in the most recent times that the demand has been made by the common people that they share in the knowledge which science gives to the race".[69]

Needed changes from the highly organized form of science for the comprehension of average individuals are as yet barely understood by

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[67] Douglass, A. A. op. cit., p. 403-404.

[68] Dewey, "The Child and the Curriculum", University of Chicago Press, Chicago, 1902, p. 24-25.

[69] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 333.

present writers of science books.[70] Writers of textbooks and courses of study, as well as classroom teachers, have too frequently ignored or violated the well-known principles of the psychological organization of subject matter, with the consequence that high school students are confronted with science in more or less degrees of logical organization.

Logical organization of subject matter is an order of arrangement for future use of what has been learned[71]; it is the order for the scientist; it represents "the perfected outcomes of learning, - its consummation".[72] For the learner it is "an ideal to be achieved, not a starting point from which to set out".[73] Science then becomes for the pupil "a new and peculiar kind of experience which the child can add to that which he has already had"[74], instead of giving the "ability to interpret and control the experience already had".[75] The logical view of subject matter is not concerned with the processes of discovery of truth, but is a cross-section of truth as it stands. It charts, maps and systematizes completed products; it has in mind the subject matter,

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70 Robinson, "The Humanizing of Knowledge", George H. Doran Company, New York, 1923.

71 Kilpatrick, "Foundations of Method", The Macmillan Company, New York, 1925, p. 302.

72 Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 221-222.

73 Dewey, John. op. cit., p. 257-259.

74 Dewey, "My Pedagogic Creed", E. M. Kellogg and Company, New York, 1897, p. 12.

75 Dewey, John. loc. cit.

not the learner. [76]

The psychological arrangement of subject matter is the order for learning. The psychologizing of a science means "to take a science as the scientist knows it (as R_n) and 'unscramble' it into such a series of E_1 R_1 E_2 R_2 E_3 R_3 . . . . as will lead the learner from where he is now through successive experiences (E) and learnings (R) until he comes to a firm grasp of the science itself". [77]

The psychological order does not mean that no order is to be used, or that pupils are to be introduced to science in a haphazared way, which leads nowhere in particular [78], except, perhaps the "accumulation of a mass of more or less interesting details". [79] Nor does the psychological order mean that the logical organization is to be left out; "it is indispensable, but it must be a final result and not a starting point". [80]

When the ill-advised attempt is made, through the teaching, textbooks or course of study, to have high school pupils study science

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[76] Betts, "Social Principles of Education", Charles Scribner's Sons, New York, 1912, p. 281.

[77] Kilpatrick, "Foundations of Method", The Macmillan Company, New York, 1925, p. 309-310.

[78] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 334-336.

[79] Bode, "Modern Educational Theories", The Macmillan Company, New York, 1927, p. 90-91.

[80] Bode, B. H. op. cit., p. 65.

in logically perfected form, the learning which is accomplished is mainly of forms and symbols; there is a lack of interest in the work of learning these externalities of the science because they are remote and aloof from ordinary human experience; and finally, the logical perfection itself of the science is lost in the process of learning by the pupil's mind.[81] Reliance upon verbal memorization by the student, instead of understanding of meanings, and dislike for intellectual studies inevitably follow the pursuit of physics and chemistry under such conditions. The use of the logical organization of a science for teaching proceeds upon the assumption that this organization can be imposed upon the mind of the student from without in "ready-made" form[82]; there is a failure to perceive that the final organization of knowledge must come as the student's own contribution, and that the nature of the organization will have individual variations in every learner. It is psychologically impossible to impose the organization from without because organization of materials is a part of the learning process itself. Such "ready-made" science becomes, in fact, not science at all for the pupil, as he learns it. In logical form science, with the possible exception of mathematics, is the poorest subject in the curriculum for teaching, and this because of the very perfection of logical organization of which many sciences are capable.[83]

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[81] Dewey, "The Child and the Curriculum", The University of Chicago Press, Chicago, 1911, p. 30-33.

[82] Betts, G. H. op. cit., p. 283.

[83] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 223.

The order of topics, then, in high school physical science cannot be the order of the science specialist; nor can the arrangement of content within the divisions be his arrangement; it is necessary to distinguish science as a means or instrument for the education of adolescents and science as subject matter or knowledge in forms preferred by the scientists themselves. In fact, the divisions between the special fields of science may be swept away by a proper application of the principles of psychological organization. The psychological order may apparently require more time but this is compensated for by "superior understanding and vital interest".[84] The pupil gains ". . . . independent power to deal with materials in his range, and avoids the mental confusion and intellectual distaste attendant upon studying matters whose meaning is only symbolic".[85]

> Students will not go so far, perhaps, in the 'ground covered', but they will be sure and intelligent as far as they do go. And it is safe to say that the few who go on to be scientific experts will have a better preparation than if they had been swamped with a large mass of purely technical and symbollically stated information. In fact, those who do become successful men of science are those who by their own powers manage to avoid the pitfalls of a traditional scholastic introduction to it.[86]

When the implications of the psychological order of subject matter are fully grasped, the principle of teaching science as a way of

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[84] Dewey, John. op. cit., p. 257-259.

[85] Dewey, John. loc. cit.

[86] Dewey, John. loc. cit.

living completely understood, the natural unity of science better appreciated, and the invalidity of the vocational aim of science teaching to develop research specialists among high school students completely recognized, the work of recasting high school science from the "forms in which the sciences are most satisfying to the mind of the trained scientist"[87] will be no longer delayed.

Educators are rapidly becoming convinced that narrowness of the subject-matter field, and barriers between subjects, may interfere with learning rather than promote it.[88] Meanings are isolated from their natural settings and limited in their relationships with ordinary experience. There is a failure on the part of the student to comprehend the wider significance of the subject, or to apply it to everyday matters of concern. Beginning students do not require and are not interested in specialized sciences.[89] When a problem arises for solution, the student does not consider whether the data for the solution belongs to this or that science; he uses what he can get from any course.[90] "Even if all students were embryonic scientific experts, it is questionable whether this (study of specialized science in high school) is the most effective procedure . . . . Considering that the great majority are

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[87] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 333.

[88] National Society for the Study of Education. Twenty-sixth Yearbook, Part II (1926), p. 21.

[89] Dewey, "My Pedagogic Creed", E. L. Kellogg and Company, New York, 1897, p. 10.

[90] Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 259.

concerned with the study of science only for its effects upon their mental habits, ... it is certainly ill-advised. Too often the pupil comes out with a something which is too superficial to be scientific and too technical to be applicable to ordinary affairs". [91] Powers has recently shown that pupils, for example, do not master the facts and principles of the chemistry now taught; neither do they acquire practical information or ability to think in that subject. [92] Caldwell has stated that the obligation to distribute knowledge is complicated by the " narrowly segregated and highly intensified divisions of the sciences". [93] Shinn has emphasized the fact that although "a so-called science course has been listed (for the high school) the pupil studied only separate units, units just as separate and distinct as Latin and history, as mathematics and English". [94] Judd has also pointed out the lack of coherence in the subjects of the high school science course. [95]

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[91] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 334-336.

[92] Powers, "A Diagnostic Study of Subject Matter of High School Chemistry", Columbia University, New York. Teachers College Contributions to Education, No. 149 (1924).

[93] Caldwell, Otis W. Some Next Steps in Science Teaching. School Science and Mathematics, Vol. XXIX (1929), p. 9-20.

[94] Shinn, Harold B. The Movement Toward a Unified Science Course in Secondary Schools. School Science and Mathematics, Vol.XIV (1914), p. 778-782.

[95] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304.

The inconsistency of the position of the high school which offers specialized science courses is commonly obvious. Generally, special training in the school for the more common industrial vocations is conspicuous by its absence. The principle of specialization is, however, applied to the subjects of the curriculum which ought to provide for a liberal education. "We follow the specialization idea where it is the very principle that ought to be most carefully avoided. . . . . It damages our high schools almost in the proportion that it is applied".[96]

The universities are beginning to understand the values of the general course for "orientation" for the student in his special field of knowledge. Finney described the "orientation course" for university freshmen as one of the most "revealing blunders" in recent college developments. "It reveals a brilliant intuition upon the part of college professors as to the meaning and aim of a liberal education. But it is placed wrong! Orientation is something that should have happened to modern youth before he came to college. . . . . If college professors want to conceive the function of the high school in their own terminology, let them call it orientation".[97]

The plan of introducing high school pupils to segregated sciences has been acquired from the colleges and universities. Pupils in the high

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[96] Finney, "A Sociological Philosophy of Education", The Macmillan Company, New York, 1928, p. 424-425.

[97] Finney, Ross. op. cit., p. 356-357.

schools have simply got more elementary treatment of college courses in the sciences.[98] As many as eight different sciences, and sometimes even twelve, are found in the high schools of a single state; these sciences contend with one another for a place in the curriculum.[99] In the university, the differentiation of science into highly specialized fields has come about because of the purposes of research;[100] it is plain that the organization of a subject according to the best plan of attack by research is not necessarily, and not likely to be, the best organization for learning or teaching. With more than a score of special sciences being urged by their devotees upon the high school curriculum it is, at any rate, clearly impossible for all to be represented there.[101]

It is not necessary that all of the sciences be represented in the high school curriculum as separate subjects. Some portions of science make close contact with ordinary life experiences; other portions are far removed. The function of high school science is intelligent concumption, rather than specialized production. The natural unity of science has

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98 Dewey, "Deomocracy and Education", The Macmillan Company, New York, 1916, p. 334-336.

99 Preliminary Report of the Committee on a Unified High School Course. School Science and Mathematics, Vol. XIV (1914), p. 166-168.

100 Creating a Curriculum for Adolescent Youth. Research Bulletin of the National Education Association of the United States, Vol.6,No.1,p.34.

101 The Place of Science in Education. A Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, December, 1927. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

been described. The overlapping of certain courses, as for example physics and chemistry, is common knowledge. The boundary line between these two sciences is almost obliterated.[102] "After all, classifications among the sciences and within any one are purely a matter of convenience. . . ."[103]

Even for research purposes, today it is recognized that a chemist must be familiar with physics, and vice versa; basic research in science wipes out all lines of division; this is so thoroughly true that chemistry can be no longer regarded as a distinct branch of physical science.[104]

> The value of science teaching today is, on every hand seriously called in question. Certainly if any situation ever demanded careful examination, it is this failure of science to establish itself in an age when science is properly thought of as the most productive type of intellectual activity.[105]

> Educators would probably be well advised if they would cut the Gordian knot by disclaiming, on the one hand, any intention of teaching "a science" below the university graduate or professional school; and, on the other hand, by asserting their readiness and determination to teach young people anywhere between the ages of four and twenty-five, or beyond, those things taken from science that it proves practicable and profitable - in cultural, health conserving, or civic senses, as well as vocational - for these persons to learn in any manner or degree.[106]

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[102] Black and Conant, "Practical Chemistry", The Macmillan Company, New York, 1928, p. 3-4.

[103] Robinson and Others, "Chemistry", Science Survey of the College of the City of New York, 1929, p. 1.

[104] Franklin, W. S. A Survey of Physics. School Science and Mathematics, Vol. XXVII (1927), p. 975-980.

[105] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304.

[106] Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 512.

Specifically, the situation should be met for the physical sciences by a new synthesis of materials; this does not mean a mere fusing of the present content of these special sciences. ". . . . The materials of instruction should be assembled from the starting point of the needs of the learner, irrespective of the content and boundaries of existing subjects. . . . . There is nothing sacred about the present content and organization of the various subjects." [107]

> There seems to be no reason against reorganizing the conventional courses (in science) along the general line sketched for general science. Each needs a reshaping of purpose and rearrangement of materials so as to bring it into harmony with valid educational principles. [108]

> With reference to English and the sciences, they need remaking from within rather than rejection. To speak thus in terms of subjects must not be taken to imply that the separate subject is the best teaching unit. [109]

Bode has pointed out the fact that the curriculum must be the expression of a social program. Materials for curriculum building may be secured by scientific research, but science does not provide the program. [110] A philosophy for the science of the secondary school may be furnished by educators but not by specialists in the physical sciences.

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[107] National Society for the Study of Education. Twenty-sixth Yearbook, Part II (1926), p. 22.

[108] Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 403.

[109] Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1926, p. 112.

[110] Bode, B. H. Determining Principles of Curriculum Construction. Educational Administration and Supervision, Vol. XII (1926), p. 217-228.

Bobbitt has stated that all of the sciences should find their proper place in the education of the individual, and the study of a specialized science or two does not accomplish this purpose.[111]

According to the Committee on a Unified High School Science Course, the important thing is not to have each special science represented in the high school, but to "include these phases of science which give the best education and open the widest opportunity to high school students".[112]

> . . . . The splendid achievements in specialized science are keenly appreciated and need all possible encouragement for future growth. Their devotees need to remember that the specialized subjects are built upon, grew out of and are supported by general science foundations.[113]

> . . . . It would be preposterous to make any recommendation if it were not for the obvious failure of the current science textbooks to meet the needs of school courses. . . . . Any suggestions for relief will doubtless get a hearing if not a respectful acceptance. . . . Why not, for the sake of experiment, try something new?[114]

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111 Bobbitt, "How to Make a Curriculum", Houghton Mifflin Company, Boston, 1924, p. 136-137.

112 Preliminary Report of the Committee on a Unified High School Science Course. School Science and Mathematics, Vol. XIV (1914), p. 166-168.

113 The Place of Science in Education. Report by the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, December, 1927.

114 Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 337.

Summary of Principles for Selection and Organization of Materials

From the investigation of the current aims for the teaching of the physical sciences in the high school [115], and from an examination of similar investigations made by others [116], it was evident that the principal goals of instruction were:

(1) Development of the ability to think scientifically

(2) Knowledge of the physical environment

(3) Understanding and skill in the application of science to everyday life

(4) Appreciation of and interest in the physical environment

These aims are supported by the consideration of the philosophy of science teaching in the secondary school and, consequently, may be employed as criteria for the selection of materials for an organization of physical science for the high school.

The first of these aims, the development of the ability to think scientifically, for various reasons, requires further elaboration. The nature of this aim has been well described by Curtis [117], with the assistance of fifty-eight high school, college and university teachers of science, and has been differentiated from the scientific method [118]

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[115] See Chapter IV.

[116] Ibid.

[117] Curtis, "A Determination of the Scientific Attitudes", Francis D. Curtis, University of Michigan, Ann Arbor, Michigan.

[118] Gates, "Psychology for Students of Education", The Macmillan Company, New York, 1923, p. 2-15.

as employed by the research worker in the experimental laboratory. The failure of the majority of people to think scientifically in everyday problems [119], and the failure of the schools [120] to teach scientific habits of thought are stressed in the writings of present-day educators. The great importance of the scientific attitude of mind for the activities of school and of life was clear from the study of current science aims [121],

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119

(a) Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 313.

(b) Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1927, p. 66-67.

(c) Kilpatrick, W. H. Subject Matter and the Educative Process. Journal of Educational Method, Vol. II (1923), p. 374.

(d) The Place of Science in Education. Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, December, 1927, School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

120

(a) Bode, "Modern Educational Theories", The Macmillan Company, New York, 1927, p. 90-91.

(b) Judd, "Psychology of Secondary Education", Ginn and Company, Boston, 1927, p. 331.

(c) Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 303-304, 313, 333.

(d) Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1927, p. 66-67.

(e) Kilpatrick, W. H. Subject Matter and the Educative Process. Journal of Educational Method, Vol. II (1923), p. 374

121

Chapter IV.

See also,

Teaching Science as a "Way of Life". Bulletin of High Points in the Work of the Schools of New York City, Vol. X (1928), No. 8, p. 17-26.

and the philosophy of high school science. [122]

> We must protect the scientific attitude of mind. It symbolizes open-mindedness, capacity for growth, and the promise of continued progress in the future. [123]

> Our young people must build such dynamic outlooks, insight, habits and attitudes as will enable them to hold their own amid change. . . . . [124]

> The chief business of science, whatever its subject matter, is to train pupils to see problems. [125]

122

(a) Burnham, "The Normal Mind", D. Appleton and Company, New York, 1924, p. 668-669.

(b) Brownell, Herbert. Psychology of High School Science and the Making of Science Teachers. School Science and Mathematics, Vol. XXVI (1926), p. 528-534.

(c) Creating a Curriculum for Adolescent Youth. National Education Association of the United States. Research Bulletin, Vol. VI, No. 1, p. 35.

(d) Dewey, "How We Think", D. C. Heath and Company, Boston, 1910, p. 156.

(e) Dewey, "My pedagogic Creed", E. L. Kellogg and Company, New York, 1897, p. 12.

(f) Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 334-336.

(g) Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1927, p. 66-67.

(h) Russell, "Science", in "Whither Mankind", C. A. Beard, ed., Longmans, Green and Company, New York, 1928, p. 65-66.

(i) The Place of Science in Education. Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

123

Bode, "Modern Educational Theories", The Macmillan Company, New York, 1927, p. 279.

124

Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1927, p. 85-86.

125

Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 333.

It is universally admitted that the pupil should acquire, as a result of his high school training, something of the scientific method of thought. [126]

All normal persons should do much of their thinking in terms of science; and all of their thinking with that intellectual perspective and proportion which can be provided only by science. [127]

No boy or girl should leave school without possessing a grasp of the general character of science, and without having been disciplined, more or less, in the methods of all sciences; so that, when turned into the world to make their own way, they shall be prepared to face scientific problems, not by knowing at once the conditions of every problem, or by being able at once to solve it; but by being familiar with the general current of scientific thought, and by being able to apply the methods of science in the proper way, when they have acquainted themselves with the conditions of the special problem. [128]

The problem of an intelligent use of science is then to create an intelligence pregnant with belief in the possibility of direction of human affairs by itself. The method of science engrained through education in habit means emancipation from rule of thumb and from the routine generated by rule of thumb procedure. [129]

For the development of the scientific attitude of mind, the two most significant suggestions, as far as subject matter is concerned, have been the use of the history of science and research [130], and the

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[126] Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 405.

[127] Bobbitt, "How to Make a Curriculum", Houghton Mifflin Company, Boston, 1924, p. 136.

[128] Huxley, "Lay Sermons, Addresses and Reviews". The Macmillan Company, Limited, London, 1903, p. 54.

[129] Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 263.

[130] The Place of Science in Education. Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, December, 1927. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

organization of materials around problems. [131]

The second aim for high school science obtained from the survey of current aims [132] is supported by writings on the theory and philosophy of education. [133] This aim was stated as knowledge of the physical environment. Snedden [134] has made clear the undesirability of too limited a definition of this aim, whereby science instruction is confined exclusively to the local physical environment of the pupil and many matters of cultural value in more remote regions ignored. Judd [135], too, in relation to this aim, has shown the function of the novel and the unusual. A close examination of the aim, relative to the others listed, shows that theoretically and practically it is implied for any functioning of the remaining three; probably, then, this aim deserves to be placed in a subordinate position to serve only as a minor general aim for instruction in physical science in the high school.

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[131] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 330-337.

[132] See Chapter IV.

[133] (a) Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 267, 334-336.
(b) Huxley, "Lay Sermons, Addresses and Reviews", The Macmillan Company, Limited, London, 1903, p. 56.

[134] Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 516-517.

[135] Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 331-332.

The third major goal, understanding of the applications of science to everyday life and the attainment of some degree of skill in making these applications, was conspicuous in the investigations of current aims [136], and is amply reinforced by philosophical considerations. [137]

Appreciation of physical nature, written science, and of scientific methods, together with the development of permanent interests in science for leisure time and a richer life, receive strong

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136
See Chapter IV.

137
(a) Betts, "Social Principles of Education", Charles Scribner's Sons, New York, 1912, p. 108-109, 281.
(b) Bobbitt, "How to Make a Curriculum", Houghton Mifflin Company, Boston, 1924, p. 129-134, 138, 141-143.
(c) Bode, "Modern Educational Theories", The Macmillan Company, New York, 1927, p. 213.
(d) Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 223, 256-257, 267, 334-336.
(e) Dewey, "Interest and Effort in Education", Houghton Mifflin Company, Boston, 1913, p. 85-87.
(f) Dewey, "The School and Society", The University of Chicago Press, Chicago, 1915, rev. ed., p. 21.
(g) Dewey, "My Pedagogic Creed", E. L. Kellogg and Company, New York, 1897, p. 11.
(h) Douglass, "Secondary Education", Houghton Mifflin Company, Boston, 1927, p. 397.
(i) Finney, "A Sociological Philosophy of Education", The Macmillan Company, New York, 1928, p. 279, 351-352.
(j) Harap,"Economic Life and the Curriculum", The Macmillan Company, 1927, p. 111-132.
(k) Judd, "Psychology of the High School Subjects", Ginn and Company, Boston, 1915, p. 333.
((l) Kilpatrick, "Education for a Changing Civilization", The Macmillan Company, New York, 1927, p. 8-9.
(m) Russell, "Science" in "Whither Mankind", C. A. Beard, ed., Longmans, Green and Company, New York, 1928, p. 70.
(n) Twiss, "A Textbook in the Principles of Science Teaching", The Macmillan Company, New York, 1917, p. 83.
(o) The Place of Science in Education. Report of the Special Committee on the Place of Science in Education to the Council of the American Association for the Advancement of Science, Nashville, December, 1927. School Science and Mathematics, Vol. XXVIII (1928), p. 640-664.

support both from current aims [138] and from the philosophy [139] of science teaching for high school.

Finally, then, the major criteria for selection of curricular materials for unified physical science in the junior or senior years of high school are stated as follows:

(1) Phases of science which tend to develop the scientific attitudes of mind, not only for science in schools but for daily living, should be selected and emphasized.

(2) Understanding of the applications of science in the activities and environment of the average individual, along with the development of fair skill in making the more common applications to everyday living, should be promoted by a suitable selection of course of study materials.

(3) Parts of science which will assist in the growth of appreciation of physical nature, of written science, and the methods of science, and parts which are likely to establish permanent interests for leisure time and an enriched life, should be selected.

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[138] See Chapter IV.

[139] (a) Betts, "Social Principles of Education", Charles Scribner's Sons, New York, 1912, p. 148, 155-162.
(b) Bobbitt, "How to Make a Curriculum", Houghton Mifflin Company, Boston, 1924, p. 129-132, 137-138, 141-143.
(c) Dewey, "Democracy and Education", The Macmillan Company, New York, 1916, p. 283-284.
(d) Robinson, "Humanizing of Knowledge", George H. Doran Company, New York, 1923, p. 88.
(e) Snedden, "Educational Sociology", The Century Company, New York, 1922, p. 520-524.

The principles of interest are probably of more value for the organization of materials of the course of study; but, to a certain extent, interests should function as criteria for selection of curricular materials for the initial stages of the whole subject, or of its divisions. The following, therefore, are listed as minor criteria for selection of subject matter:

(1) Knowledge of the physical environment should be assured by proper selection of materials for a course of study.

(2) Within limits which have been described, the interests of students in scientific matters should control in the selection of subject matter.

For the organization of materials of the physical sciences for the secondary school, the following principles have been established:

(1) The unity of science is found in the fundamental nature of written science which possesses inherently no divisions into subject matter fields.

(2) The unity of science is revealed in the wholeness of the natural environment.

(3) The unity of science is apparent from the nature of experience itself in which science is best regarded as a way of behaving which provides for control and enrichment of experiences.[140]

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[140] Kilpatrick, "Foundation of Method", The Macmillan Company, New York, 1925, p. 305-306.

(4) The principal function of interest in science is to provide for arrangement of subject matter in psychological organization.

(5) Because of the importance of the attitudes of science for intelligent daily living, the materials of physical science should be arranged so as to present problems instead of simply solutions of problems.

Chapter VI

THE TENTATIVE OUTLINE OF AN INTEGRATION OF MATERIALS IN PHYSICAL SCIENCE FOR THE JUNIOR OR SENIOR YEARS OF HIGH SCHOOL

The General Method of Selection and Organization of Materials

The items of this tentative outline of materials in physical science for the junior or senior year of high school were secured from modern textbooks in the physical sciences, recent courses of study, standard treatises in the physical sciences, and other scientific writings in periodicals, bulletins, etc.

Lists of these items were made separately for each special science and submitted for rating to outstanding instructors in secondary and higher institutions. The instructor was permitted to rate only the items of his own field of specialization.

Recent valuable curricular contributions from progressive centers throughout the country were also utilized as sources of items.

In the process of selection of items for inclusion due consideration was given to the degree of unanimity of agreement of the judges who rated the items for high school use; doubtful items from this standpoint were generally excluded. The more important basis of selection was by the test of the criteria established in Chapter V. In the last analysis, the items utilized were therefore selected on the bases of authoritative works in the physical sciences; judgment of expert instructors in these sciences in high schools, teachers' colleges and universities; judgment of specialists in science education and criteria derived from the psychology and philosophy of education.

Particular Methods Used with Special Sciences

Astronomy

In astronomy, high school courses [1] were rare but were used as far as found; many standard works were available as well as textbooks. Items were rated by two high school [2] teachers of astronomy and two college [3] professors. Krank's [4] investigations were used extensively.

Chemistry

Many courses of study, textbooks and standard treatises were available for chemistry. The items in chemistry were divided into two lists; one was rated by eight and the other by seven teachers of chemistry

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[1] "Science", Curriculum Bulletin No. 210, 1928, p. 54. San Francisco Public Schools.

[2] High School for Girls, Dorchester, Mass.; Lincoln High School, Jersey City, New Jersey.

[3] Rutgers University; Vassar College.

[4] Krank, Erma M. Curriculum Study in Astronomy. School Science and Mathematics, Vol. XXVI (1926), p. 952-956.

in high schools [5], teachers' colleges [6] and universities [7]. Much use was made of the revised "Standard Minimum High School Course in Chemistry" of the American Chemical Society [8], and of the report of the Sub-Committee on Chemistry [9] of the Commission on Unit Courses and Curricula of the North Central Association of Colleges and Secondary Schools. The pamphlet on chemistry used in the "Science Survey" course of the College of the City of New York was suggestive for materials and organization. [10]

Meteorology

For meteorology, reliance was necessarily upon standard works rather than textbooks, for curricular material. No case was discovered

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[5] University School, Madison, Wisconsin; Cleveland High School, St. Louis; Central High School, Austin, Minnesota; High School, Laramie, Wyoming; Emerich Manual Training High School, Indianapolis, Indiana.

[6] Eastern Illinois State Normal School, Charleston, Illinois; Shepherd College State Normal School, Shepherdstown, West Virginia; Harris Teachers College, St. Louis; Concord Teachers College, Athens, West Virginia; State Normal School, Steven's Point, Wisconsin.

[7] Teachers College, Columbia University; University of Minnesota; Knox College; University of Washington; Morris Harvey College, Barboursville, W.Va.

[8] Correlation of High School and College Chemistry. Journal of Chemical Education, Vol. I (May, 1924), No. 5.

[9] Report of the Committee on Standards for Use in the Reorganization of Secondary School Curricula. North Central Association Quarterly, March, 1927.

[10] "Chemistry". Science Survey. College of the City of New York, New York, 1929.

of the teaching of the subject as a special science in high school, and, even in universities, the subject was rarely found. Three college[11] professors of meteorology were finally secured to rate a list of items, and a suggestive letter was received from a fourth.[12]

Mineralogy

In mineralogy, numbers of standard works and textbooks for college classes were available. In no instance was the course found as a separate subject in high schools. Four university professors[13] of mineralogy rated the items submitted.

Physical Geography and Physical Geology

Many of the items of physical geography and physical geology were necessarily identical. A number of courses of study[14] for these

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[11] University of Arkansas; Wittenberg College; Yale University.

[12] Johns Hopkins University.

[13] University of Chicago; University of Delaware; Princeton University; University of Wisconsin.

[14] (a) Course of Study for Science. Bulletin No. 105 (1924), p. 38-52. Department of Education, Oklahoma City, Oklahoma.

(b) Geography for the High School. Curriculum Bulletin (1926), No. 26. St. Louis Public Schools.

(c) High School Geography. John Marshall High School, Richmond, Virginia.

(d) High School Manual and Course of Study. Bulletin No. 12 (1928), p. 87. Department of Public Instruction, Lansing, Michigan.

(e) Science. Curriculum Bulletin (1928), No. 210, p. 52,55. San Francisco Public Schools.

(f) Syllabus in Physical Geography. University of the State of New York. State Education Department, Albany, New York.

subjects in high school were investigated for items, as well as many textbooks and standard works on the subjects. The items were rated by two college[15] professors and three high school[16] teachers of the subjects. The pamphlet on geology[17] used in the "Science Survey" course of the College of the City of New York was valuable.

Physics

A large number of standard works, textbooks, courses of study, syllabi, etc., were used as sources of materials in physics. The list of items was divided into two parts, each of which was rated by fourteen instructors in physics in high school[18], teachers' college[19] or university[20].

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[15] University of Kansas; University of Oklahoma.

[16] Austin High School, Chicago; Beaumont High School, St. Louis; High School, Iowa City, Iowa.

[17] O'Connell, "What is Geology?" Science Survey. College of the City of New York, 1928.

[18] East High School, Wichita, Kansas; High School, Davenport, Iowa; Technical High School, Atlanta, Georgia; English High School, Boston; Harrison Technical High School, Chicago; High School, Milton, Delaware; High School, New Castle, Pennsylvania; Northeast High School, Kansas City, Missouri; Austin High School, Chicago; High School, Bloomington, Indiana; Technical High School, Providence, Rhode Island.

[19] Teachers College, Boston; Concord State Teachers College, Athens, West Virginia; Indiana State Teachers College, Terra Haute, Indiana; State Normal College, Bowling Green, Ohio; Fairmont State Teachers College, Fairmont, West Virginia; State Teachers College, San Marcos, Texas; Harris Teachers College, St. Louis (two instructors).

[20] University of Minnesota; University of Nebraska; University of Washington; University of Illinois; Miami University; Reed College; West Virginia University (two instructors); the editor of the "Electrical World" magazine, and former proffessor of electrical engineering, Yale University.

The Tentative Outline

The general aims, specific objectives, pupil activities and teaching procedures relative to the major divisions of the outline of the organization are briefly formulated as follows:

I. The Celestial Sphere

A. The Stellar System

General Aims:

Development of appreciation of the extent, complexity and order of the universe; establishment of permanent interests in the heavenly bodies. Learning of important facts and theories concerning the heavens, and of the ways in which the more remote heavenly bodies have influenced man's life. Arousal of scientific attitudes by means of unsolved problems of the universe.

Specific Objectives:

Knowledge of and interests developed in meteors, comets, stars, common constellations, nebulae, the Milky Way. Daily and yearly changes in positions of stars; changes with latitude. Origin, evolution and fate of the physical universe; island universes. Discoveries of stars and comets. Galileo, and other great astronomers. Interesting facts about astronomical instruments and their uses: telescope, camera, transit instrument.

Applications of knowledge of the heavens to man's activities: sidereal time, surveying, navigation, astrology.

Pupil Activities:

Observations: meteors, stars and constellation with a chart, Milky Way, nebulae, apparent daily motion of stars.

Use of photographs, reading, discussion.

Procedure:

Suggestions of the questions to be raised: What is a "shooting star"? Is there danger of a comet hitting the earth? What are the names of the brightest stars, and how can they be identified? What is the Milky Way? Do the stars move? Why do sailors observe the stars? Can one tell his future by the stars? Where is the largest telescope? Who were the great astronomers? How did the universe originate? Is there an end to space?

Pupil observations should be recorded and reported. Problems on time, latitude and longitude may be given.

B. The Solar System

General Aims:

Development of interest in the planetary system by means of the more striking facts and theories. Cultivation of scientific attitudes by questions and problems. Knowledge of the effects of the sun, planets and moon upon man and the earth.

Specific Objectives:

Knowledge of interesting facts about the planets, satellites and asteroids; planetary motions, Kepler's laws of planetary motions.

Newton's law of universal gravitation; mass, density, spedific gravity. Newton's laws of motion.

The Ptolemaic and Copernican systems.

Origin of the solar system: nebular hypothesis, hypothesis of dynamic encounter, planetesimal and tidal theories.

Knowledge of the sun: age, dimensions, distance, telescopic appearance, layers, corona, sunspots, etc.

The sun's light: speed of light, Jupiter's satellites and the light equation. Shadows and solar eclipses.

Illumination and photometry.

The corpuscular and wave theories of light; the ether and light.

Interference, polarization, refraction, white light, colors, the rainbow, the solar spectrum and spectroscope.

The sun's heat. Absorption and radiation of heat, thermometry, the calorie and B. T. U. Heat by friction, collision and compression. Theories of planetary and solar temperatures.

Electromagnetic radiation from the sun.

Knowledge of the earth as a planet: shape, dimensions, distances and areas. Latitude, longitude.

Gravitation: stable equilibrium, laws of falling bodies, velocity, uniformly accelerated motion.

Newton's laws of motion, momentum, force.

Rotation of the earth, the poles, Foucalt's experiment.

Orbital motion of the earth: the sun's apparent annual motion.

The moon: motion, phases, eclipse. Conditions on the moon from telescopic and photographic studies.

Observatories: telescopes, cameras, spectroscopes.

Light: reflection, diffusion, refraction, visibility, images formed by lenses and mirrors, achromatic lenses, the opera glass, prism binocular, and telescope.

The magnetic field of the earth: compass, declination, dipping, magnets, laws of magnetic action, magnetic induction, lines and fields of force.

Effects of the sun's light and heat upon man, animals, plants: health, growth, comfort, daylight, photography, the human eye.

Effects of electromagnetic radiations from the sun: magnetic storms, compass, telegraph, Northern Lights.

Day and night: variations according to time and latitude, climatic effects.

Climatic zones of the earth.

Measurement of time on the earth.

The tides.

The spring balance, and weights of bodies at poles and equator. Paths of projectiles at surface of earth.

Navigation: latitude and longitude, mariner's compass, Sperry gyrocompass.

Pupil Activities:

Observations: planets, sunspots, Northern Lights, solar spectrum, rainbow, shadows, telescopic observation of moon, camera, compass, sun dial, tides.

Experiments: diffusion, reflection, interference, polarization, refraction, spectra, photometry, radiation, lenses, prisms, use of thermometers, heat measurement, falling bodies, magnetic lines and field.

Mathematical problems: velocity, acceleration, force, momentum, candle power, heat, temperature.

Readings and discussions.

Procedure:

Class reports on observations. Problems, observations and experiments should accompany other activities.

New topics introduced, interests aroused, and scientific attitudes awakened by having problems raised. Suggested problems: How can one distinguish the planets from the stars? Are any of the planets habitable? Are the light and heat of the sun decreasing? What causes an eclipse of the sun? What are sun spots? What is the "midnight sun"? Why does the length of day and night vary? How did the calendar originate? What causes tides? How is a submarine steered?

Much use should be made of the history of astronomy and of physics. Examples: How was Neptune discovered? What discoveries did Galileo make?

II. The Atmosphere

General Aims:

Interrelations of man and the earth with the atmosphere. Scientific attitudes about problems of the atmosphere. Interest in atmospheric phenomena. Knowledge of the physical properties and chemical constituents of the gases of the atmosphere, and of the laws governing atmospheric phenomena.

Specific Objectives:

Sunlight in the atmosphere: diffusion, color of air, twilight, refraction effects, atmospheric dust.

Effects of sun's heat on atmosphere: temperatures, convection currents. Air heating and ventilating systems.

Solar electromagnetic radiations in the atmosphere: the aurora, sun spots and the temperature of the atmosphere.

Measurements of atmosphere: height, weight, barometry.

Compressibility and expansibility of air; Boyle's law, laws of Charles and Gay-Lussac; pneumatic appliances: air-gun, door-check, pumps, siphons. Density of gases; measurement of gases.

Principle of Archimedes: balloons and airships. Navigation in air.

Water in the atmosphere: humidity, clouds, fogs, precipitation, evaporation.

Weather: storms, tornadoes, hurricanes, cyclones and anti-cyclones, weather maps, prediction of weather, weather instruments.

Electrical phenomena of atmosphere: lightning, positive and negative electricity, electrification by induction.

The electron theory of electricity, electric charges on conductors, lightning rods, electrical potential and capacity, condensers.

Electrical radiations: the radio.

Composition and resolution of forces, inclined plane, pendulum, kite, airplane, Bernolli's principle.

Kinetic theory of gases, molecular motions, Avogadro's law, Brownian movements, diffusion of gases, absorption by liquids and solids, molecular theory of matter.

Sound waves: speed, pitch, quality, intensity, reflection, reenforcement, interferences, acoustics.

Musical sound: wind, membrane and stringed instruments.

Sound as a sensation.

Chemical elements of the atmosphere; oxygen, nitrogen, argon, carbon dioxide, cycle of carbon dioxide. Oxidation and nitrification. The nitrogen cycle.

Pupil Activities:

Observations: color of air, twilight effects; changes in temperature, winds, and pressure for a week; aurora, sun spots; gas meters, pumps, siphons; local precipitation for a week, hygrometer readings for a week, clouds, weather maps and predictions; lightning, lightning rods, condenser of a radio set; Brownian movements, diffusion and absorption of air; phonograph, dictaphone, echo, a wind instrument, relation of speed of light and of sound; temperature and humidity in relation to ventilation; nodules on the clover plant, carbon dioxide in breathed air.

Experiments: Boyle's law, charges on conductors, induced electrification, inclined plane, pendulum, speed of sound, laws of vibrating strings and air columns, percentage of oxygen in the air, nitrogen, carbon dioxide.

Mathematical problems: pressure of air, Boyle's law, calculations of gas bills, laws of Charles and Gay-Lussac, problems on gas measurement; principle of Archimedes, making a rainfall curve for a year from date furnished, humidity, forces, wave length of sound.

Reports in class of observations and experiments, readings and discussion.

Procedure:

Suggested problems to be raised: Why does it not get dark when the sun sets? Is there any relation between sun spots and the weather?

Why does water boil more quickly on a mountain? Why does a balloon rise in the air? How does an airplane fly? How are clouds formed and what becomes of them? Why are tornadoes destructive? Are lightning rods useful? How is a baseball made to curve? What causes the echo? What happens when substances burn? How do plants get their nitrogen and carbon dioxide? Some problems should be raised which cannot be answered at the time.

Physical and chemical discoveries connected with the topics of the atmosphere should be considered, and the lives of some of the great scientists who made these discoveries.

III. The Hydrosphere

General Aims:

Knowledge of the important facts and principles about water on the earth's surface and in its crust. Knowledge of the relations of the hydrosphere to man, animals, plants and the land. Appreciation and interest developed in the parts that water has played in making the land what it is, and of its importance to life on the earth. Stimulation of scientific attitudes by means of the problems involved.

Specific Aims:

Contact of atmosphere and hydrosphere: solution of air and gases in water, waves in water; light passing from air to water and vice versa; index of refraction; evaporation, vapors, effect of air upon evaporation; absorption of heat and light by water, climatic effects.

Description of the hydrosphere: marine and continental waters, areas, depths, temperature; ground water, inland seas, lakes, rivers and oceans considered briefly.

Introductory treatment of denudation of the land by the atmosphere and hydrosphere.

Molecular forces in water and liquids: cohesion, adhesion, surface tension, capillary phenomena.

Molecular motions in water and liquids: evaporation and diffusion.

Boiling of water and liquids: boiling temperatures, effects of pressure, heat of vaporization, condensation. Steam, heating by steam, steam engines, distillation, ice manufacture, refrigeration, pressure cookers, vacuum pans.

Expansion and contraction in liquids; density of water, circulation in water, freezing of a deep lake.

Solidification and fusion; the ice-cream freezer.

Heat conduction, convection and radiation in water and liquids; ocean currents, hot water heating system, automobile radiator.

Law of mixtures for heat in liquids.

Principle of Archimedes as applied to liquids: iceberg, ship, submarine, specific gravity. Hydrometers.

Pressure in liquids and water, force and pressure, Pascal's law, the hydraulic press and elevator, spouting oil and gas wells, city water system, hydraulic ram.

Water as a solvent, other solvents, solutions, saturated solutions, freezing and boiling points of solutions, fractional distillation; sea-water, mineral springs, carbonated water and beverages.

Purification of water: distillation, filtering, water meters.

Ground water: water table, springs, wells, geysers, artesian wells, hot springs, intermittent springs.

Streams: floods, river systems, drainage, grade, current, depth.

Lakes: fresh and salt; swamps.

Glaciers and ice.

Irrigation and water power.

Chemical nature of water: composition by volume and weight, analysis and synthesis of water. Law of definite composition; law of multiple proportions. Natural and pure water; chemical properties of water; its importance in chemistry.

Water in foods and the human body: water in plants and the soil.

Knowledge and interest in scientific discoveries relating to the hydrosphere.

Pupil Activities:

Others will be suggested: shooting at a mark under water, observation of water waves, evaporation of water in vacuums, drying a wet cloth on a rainy day, comparison of winter temperatures for a sea-coast city and an inland town at the same latitude; experiments on cohesion, adhesion, surface tension, capillarity, diffusion; the boiling points of alcohol and water compared experimentally, fractional distillation of alcohol and water, measurement of heat of condensation of steam, observation of a model steam engine, visit to an ice factory, effect of pressure on boiling points experimentally determined, expansion of water due to heat studied experimentally, water as a heat conductor studied by experiment, observation and report on a hot water heating system, law of mixtures by experiment, specific gravity of gasoline by hydrometer, boiling point of a solution of salt and water, reading a water meter, electrolysis of water, synthesis of hydrogen and oxygen, evaporation of a natural water for residue, etc.

Readings, reports, discussions.

Procedure:

Avoid separation of class work and experimentation; experiments are essentially to "answer questions addressed to nature". Arouse and maintain problem solving attitudes by questions. Suggestions: How do you shoot at a fish under water, and why? What is the motion of a cork floating on water waves? Why will a needle float on water? Why does oil rise in a lamp wick? What is the temperature of steam? How would you cool a watermelon without ice, refrigerator or cellar on a sunny day in Arizona?

Study Archimedes and other scientists who have made discoveries involving the hydrosphere.

IV. The Lithosphere

General Aims:

Acquisition of knowledge of the rocky sphere of the earth and, especially, of the terrestrial lithosphere as the principal seat of human activities based upon the physical sciences. Development of interests in the relations of man to the land surfaces of the earth and their contents, and of appreciation of the functions of the physical sciences in the life of man on the surface rocks and soil of the globe; awakening and strengthening of scientific attitudes with respect to the problems of the physical sciences involved in these relations and activities.

Specific Objectives:

Description of the lithosphere: terrestrial and sub-oceanic divisions, extent of land and water; continental platforms: mountains, plateaus, plains, continental shelf; ocean basins; origin of continents and ocean basins.

Mechanical relations of the lithosphere with the hydrosphere and atmosphere. Processes of destruction: rain, frost, snow, ice, running water, underground water, solution, work of the ocean, temperature changes of the atmosphere, wind, lightning. Processes of construction: continental deposits, such as mantle rock, wind-laid deposits, work of ground water, river-laid deposits, deposits by moving ice, lake and swamp deposits. Marine deposits, such as those of the shore, shallow water and deep sea.

Chemical relations of the lithosphere, atmosphere and hydrosphere. Oxidation: slow oxidation, oxides of metals, mineral oxides. Carbonation: action of atmospheric and hydrospheric carbon dioxide upon elements and compounds of the earth's crust, carbonates, "hard" water, "softening" of hard water. Hydration: hydroxides in nature.

Geological time: origin and age of the earth; divisions of geological time; story told by the rocks. Brief consideration.

History of geology as a science and use of geology to man, briefly.

Topography: plains, plateaus, hills, mountains, shore lines, etc. Maps, charts and models of land forms and the earth's surface. Transportation: river, canal, lake, coastal, ocean, pipe line, railway, roads, trails, air.

Light and solids: radiation, reflection, absorption and transmission by land masses and solids; luminous and non-luminous bodies, opaque and transparent substances, crystals, vision, moving pictures, the microscope; color phenomena: color of bodies in white and colored light, compound and complementary colors, colors of pigments, three color printing, colors in thin films.

Heat and solids: radiation, reflection, absorption and transmission by land masses and solids; radiation from bodies at different temperatures, the invisible spectrum, radiometer, relation of radiators and absorbers; reflection of heat from the land and temperature effects; conduction of heat by solids, expansion of solids, and applications; specific heat of solids; fusion and "freezing" of solids, ice; pressure and fusion, ice; change of volume with change of state; melting points of amorphous and crystalline substances.

Energy transformations in fusion; relation of heat and work, friction, collision, compression. The law of the conservation of energy; other examples of the law: a power plant; the importance of this basic law in physical science. "Perpetual" motion machines.

Work and mechanical energy: definition and measurement of work; work and the simple machines; the principle of work; power and energy and their measurement; law of frictionless machines; friction; efficiency of machines; law of all machines; mechanical equivalent of heat; internal combustion engines.

Molecular motions and forces in solids: diffusion of solids, tenacity, elasticity, Hooke's law, cohesion, adhesion. Molecular nature of matter.

Chemical elements of the atmosphere, hydrosphere and lithosphere: compounds and mixtures, metals and non-metals, physical and chemical changes, combination of elements, decomposition of compounds, families of elements.

Detailed study of oxygen, ozone, oxidation, oxides, uses of oxygen.

Study of the element hydrogen; reduction, water, hydrogen peroxide.

Nitrogen, ammonia, oxides of nitrogen (briefly), nitric acid, common nitrates; nitrogen cycle, fixation of nitrogen; uses and applications.

Molecular and atomic theory; molecular and atomic weights.

Symbols, formulas, equations; problems based on equations. Laws of definite and multiple proportions. The principle of the conservation of matter.

Chlorine, the halogens and compounds; hydrochloric acid; common salt; applications.

Carbon and its oxides: carbon dioxide, carbon monoxide; chemical reactions in stoves, grates, furnaces, automobile engines, coal mine explosions.

Valence; electrical nature of atoms, electrons and protons; use of valence.

Sodium, potassium, and their common compounds; solubility of the compounds.

Solutions: electrolysis of solutions, electrolytes and non-electrolytes. Colloids; applications important.

Acids, bases and salts: properties, tests, neutralization, use of indicators.

Ionization: nature, electrolysis, acids, bases, salts, displacement series.

Chemical reactions: speed, energy, temperature, reversible reactions, equilibrium, catalysis. Principle of conservation of energy.

Sulphur and its common compounds. Uses. Sulphuric acid.

The periodic law for the classification of the elements.

Other compounds of carbon: hydrocarbons, such as petroleum and its products, destructive distillation, fuel and lighting gases, flames. Coal tar compounds, such as benzene, carbolic acid, dyes, foods, medicines. Carbohydrates, such as sugars, starches, cellulose. Textiles and paper. Alcohols, such as grain and wood alcohols. Organic acids, such as acetic, tartaric, acids of fats and oils. Foods, such as proteids, carbohydrates, and vitamins. Soaps, glycerin, explosives.

Phosphorous and phosphates; fertilizers, matches.

Silicon and boron; silica, silicates, carborundum, borax.

Calcium, magnesium, and common compounds: carbonates, oxides, hydroxides; calcium cyanamide, bleaching powder, phosphate rock; silicates of magnesium; gypsum; mortar, cement, concrete, plaster of Paris.

Metals and non-metals: common ores, principles of metallurgy, refining of metals, alloys, ways of preparing metallic salts.

Common metals, occurrence in nature, metallurgy, properties, uses, alloys, common compounds and their uses: copper, mercury, silver, zinc, tin, lead, aluminum, iron.

Some of the rarer elements: gold, platinum, radium, tungsten.

Rocks of the earth's crust: sedimentary, igneous, metamorphic; physical and chemical properties of rocks; tests for common rocks; strata, joints, folds, faults, mountain structure.

Sedimentary rocks: mechanical, organic and chemical deposits. Metamorphic rocks: foliated and non-foliated. Igneous rocks: coarse grained, fine-grained, glassy, fragmental. Common rocks of each of the three classes studied in detail.

Soils: transported and residual, origin, kinds, tests, capillarity, fertilizers.

Minerals: mineral resources, formation of mineral deposits, chemical classes of minerals. Physical characteristics of minerals: cleavage, fracture, hardness, magnetism, specific gravity, luster, color, transparency, streak, taste, odor. Common crystal systems: cubes, prisms, octahedrons. Theory of crystalline structure. Water of crystallization, efflorescence and deliquescence. Apparatus used in mineralogy; tests for minerals. Conservation of minerals and mineral resources. Study in some detail the following common minerals:

Carbon, diamond and graphite; native sulphur, gold, silver, and platinum; mercury, cinnabar; copper, native, chalcopyrite, malachite, azurite; lead, galena; iron, siderite, hematite, magnetite, limonite; manganese, pyrolusite; zinc, sphalerite; aluminum, bauxite; calcium, calcite, fluorite, apatite, gypsum; magnesium, dolomite; sodium, halite; silicon, quartz, opal; tin, cassiterite.

Gems and precious stones.

Radioactive elements, radium and its disintegration; electrical theory of matter; electromagnetic theory of light; cosmic rays; magnetic radiations from the sun; the earth's magnetic field; magnetic substances in the earth, natural magnets.

Bar and horsehoe magnets; laws of magnetism, magnetic materials, magnetic induction, retentivity and permeability, lines and fields of force, theory of magnetism, saturation.

Static electricity: friction, positive and negative electricity, conductors and nonconductors, electrostatic induction, the electron theory, equality of plus and minus charges, distribution of charge on conductors, potential and capacity.

Electricity in motion: magnetic effects, the galvanic cell, comparison of galvanic cell and a static machine; chemical effects of an electric current: electrolysis, electroplating, electrotyping; electromagnets, shape of the magnetic field about a current; properties of coils; measurement of electric currents; series and parallel circuits and cells; the electric bell and telegraph; resistance and electromotive force; Ohm's law; primary cells; secondary cells; heating effects of an electric current; fuses and circuit breakers.

Induced currents: principles of the dynamo and motor; dynamos; motors; induction coils and transformers; power transmission; dangers of electricity.

Knowledge and interests in the many discoveries of scientists concerning the lithosphere and man's activities thereon; study of the lives of some of these great scientists.

Pupil Activities:

Observations: effects of water erosion; evidence of glacial action; action of wind and frost on rocks and soil; evidence of deposition;

fossils; strata; identification of rocks of the region; coal or other mine, quarry; railway "cut"; use of topographic and other maps; examination of a microscope; flames; soil formation; common rocks and minerals; natural magnets; cells and batteries; dynamos and motors; induction coils; transformers; automobile ignition system; the telephone; reading an electric meter; automobile "starter"; house wiring circuits; visit to a power plant.

Collections: common minerals and rocks.

Experiments: making of a topographic map; color disc; radiometer; radiators and absorbers of heat; expansion coefficient of a metal; specific heat; pressure and fusion; melting points; simple machines; Hooke's law; physical and chemical changes; hydrogen; oxides; alkalis; carbonates; softening of "hard water"; nitrogen; ammonia; nitric acid; chlorine; hydrochloric acid; electrolysis; properties of acids, bases, salts; flame tests of elements; sulphur and sulphuric dioxide; sulphuric acid; hydrogen sulphide; tests for sugars and starches; tests for textiles; preparation of a soap; common food tests; phosphorus; bleaching powder; tests for common rocks and minerals; simple soil tests; capillarity; tests for fertilizers; water of crystallization; tests for simple "unknowns"; making a permanent magnet; lines and fields of magnetic force; magnetic induction; friction electricity; conductors; electroplating; electromagnet; magnetic field about a current; measurements of currents; induction coil; transformers; efficiency of an electric lamp or cooker. Many other experiments will be suggested in the fields of magnetism and electricity.

Procedure:

Suggested problems for observation, experimentation or class discussion: How was the Grand Canon made? Were the glaciers ever in this region? Is the sea getting to be deeper, or not? Why is the ocean salt? What happens in a mine explosion? How does a fire extinguisher work? Is "perpetual motion" possible? What would happen if a balloon filled with hydrogen ignited? What substance will dissolve gold? How is gasoline made? How can you test gasoline for the automobile? How can you test for glucose in candy? How would you test soil for plant foods? How are diamonds mined? By what part of the wire is an electric current carried? What is a "short circuit"? How would you find the efficiency of an electric toaster? How would you compare the efficiency of a tungsten lamp with a carbon filament lamp?

New topics should be introduced by problematic questions, and questions relating to striking phenomena. There should be no divisions between observations, experiments and class work; experiments should be suggested by the problems raised.

Very many interesting scientific discoveries are related to the topic, the lithosphere.

V. The Centrosphere

General Aims:

Knowledge and interest in the conditions of the interior of the earth; relations of these conditions to man; development of scientific attitudes through the problems involved.

Specific Aims:

Description of the centrosphere: density, temperature, magnetic state; changes in substances from the surface of the earth to the interior.

Diastrophism: elevation and sinking of the land; types of earth movements, earthquakes, continent-forming movements, mountain-building movements; causes of diastrophism.

Vulcanism: intrusions, such as dikes, sills, laccoliths, batholiths; extrusions such as volcanoes, fissure eruptions; effects of vulcanism; distribution of volcanoes; subordinate volcanic phenomena, such as fumaroles, mud volcanoes, hot springs, geysers; causes of vulcanism.

Igneous rocks: intrusive and extrusive; acid and basic. Coarse-grained: granites and their minerals, uses of granites; syenite; diorite; gabbro; peridotite. Fine-grained: felsites, andesites, basalts or traps. Glassy rocks: obsidian, pitchstone. Fragmental rocks: tuff, volcanic breccia.

Metamorphic rocks: non-foliated: marble, quartzite; foliated: slate, gneiss, shists. Causes of metamorphism.

Interior structure of the earth: rock distortion, strength of earth's crust, isostasy.

Pupil Activities:

Observations of any effects of vulcanism in the region, such as dikes, sills, hot springs, geysers.

Collection and observation of igneous and metamorphic rocks; identification of these rocks.

Readings, reports, discussions.

Procedure:

Suggested questions: What is the deepest mine in the world? Where is the deepest well? Is the interior of the earth solid or liquid? How would gravity act at the center of the earth? Which is more durable, marble or granite? How can you tell marble from granite? Is there any relation of mineral veins to igneous or metamorphic rocks?

Chapter VII

SUMMARY AND CONCLUSIONS

The recent general tendency toward reorganization of subject matter into larger and broader units for instructional purposes in the secondary school has revealed itself in the sciences; a major result has been the establishment of general science as the introductory course in science for high school pupils; to a lesser degree, a unification of the traditional subjects of botany, zoology and physiology has led to the teaching of general biology in many progressive high schools.

The sciences of the later years of the secondary school have, for the most part, resisted any great reorganization, and have continued to be taught as highly specialized subjects. These sciences, and particularly physics and chemistry, are generally regarded as difficult by high school students, and have failed to gain great favor among them. Students typically graduate from high school with knowledge of not more than one specialized science, in addition to general science. In many cases, no science, outside of general science, is elected, and, sometimes, even general science is omitted from the student's program.

The important functions of physical science in modern life for liberal culture, industry, daily living and reliable thinking have been described. In these functions, the facts and principles of the specialized subjects, physics and chemistry, are of basic value; in spite of this, these most prominent subjects in the physical sciences of the secondary school are studied by small percentages of the pupils who enroll in the public high schools.

The problem of this research, then, has been the consideration, philosophically and psychologically, of the question of a new synthesis of the materials of the specialized physical sciences for use in the later years of the high school; and of the formulation of a tentative outline of this integration.

An investigation of the interests of high school pupils in the physical sciences was undertaken with two objects in view: (1) arrangement of materials of an integration in accord with these expressed interests, and (2) selection and emphasis, to some degree, in relation to interests in the physical sciences. The chief interests of high school students in these sciences were found to be in astronomy as a subject; experimental and practical aspects of chemistry; rocks, minerals and land forms in geology and physical geography; climate in meteorology; electricity in physics, and experimentation for all the sciences. Electricity was the most interesting subject in the physical sciences. Generally, theory and technical matters in the physical sciences did not represent strong interests; the mathematical elements of these sciences were the most uninteresting matters in them to high school boys and girls.

A study of the psychology of interest was made in order to supplement the investigation of the interests of high school students in the physical sciences. The function of interest in a learning situation has been described and applied to these sciences; the special value of interest in science for development of appreciation and permanent attitudes and interests toward science were emphasized. It became evident that the cultural values of these sciences depended mainly upon appreciation developed through interest. The use of the novel, as opposed to the familiar and usual environment, was found to be the best approach to the physical sciences, or to any subdivision of them. A chief value of the consideration of the interests of high school students was found to lie in their use for the arrangement of subject matter in form suitable to the learner in advance of the learning situation itself. The high importance of the cultivation of interest in problem solving as essential to the development of the scientific attitude of mind became apparent, and has been described at some length.

The prevalent aims for high school physical science were investigated through letters, questionnaires, and a study of current literature. The following general aims stood conspicuously among the wide variety of current aims found:

(1) The teaching of physical science in order to influence the thought processes of the student so as to lead him to habits and attitudes of scientific thinking in school and life situations generally

(2) Knowledge of the natural environment

(3) Understanding of the applications of science in everyday affairs

(4) Enjoyment of nature

The four major goals of instruction in the physical sciences, as discovered through the investigation of current aims, were found to be substantiated by principles derived from the philosophy of education. Philosophic analysis of these major aims reduced them finally to the number of three:

(1) Development of scientific attitudes

(2) Understanding of and some degree of skill in the applications of science to everyday life

(3) Appreciation of and interest in the physical environment

Upon the bases of these major aims, and the psychology of interest, principles for selection of materials for an integration of the physical sciences were formulated as follows:

Major Criteria for Selection of Materials

(1) Materials of the physical sciences which tend to arouse and strengthen the scientific attitude of mind should be selected and emphasized.

(2) Materials which provide for understanding of the applications of science to daily affairs, and which promote the development of skills in making these applications should be selected.

(3) Those parts of the physical sciences which will assist in the growth of appreciation of physical nature, of the written accounts of physical nature and of scientific method, and which are likely to build permanent interests in physical science, should be selected.

Minor Criteria for Selection of Materials

(1) Knowledge of the physical environment should be assured by suitable selection of materials.

(2) Within limits, the interests of students in scientific matters should control in selection.

From a philosophic consideration of the nature of scientific knowledge and its relations to human experience and learning, the following principles for organization of materials of the physical sciences were formulated:

Criteria for Organization of Materials

(1) The unity of science is apparent from the fundamental nature of science which intrinsically possesses no divisions into subject matter fields.

(2) The natural environment is a unit in the sense that it is permeated with common matter and forces.

(3) Science, psychologically and from the standpoint of learning, is best regarded as a way of behaving so as to intelligently control and enrich experience which, for the individual, is unitary.

(4) The chief function of interest in science is to help provide for psychological organization, which is the order of experience in learning.

(5) The materials of the physical sciences should be arranged so as to present problems to the learner, in order to cultivate the scientific attitude of mind.

In the larger sense the conclusions of this work are best represented by the integration of the materials of the special physical sciences as tentatively outlined in the preceding chapter (Chapter VI). For this synthesis the following specialized subjects in the physical sciences were utilized: astronomy, chemistry, meteorology, mineralogy, physical geography, physical geology and physics.

In essence, this integration is an organization of physical science in terms of the learner rather than in terms of the expert; it is school science rather than scientific knowledge; it is science for the adolescent student, instead of science for the research specialist.

In tentative outline, there is given a basic organization which may be utilized for detailed construction of a course of study in unified physical science for the later years of high school. Only enough detail is given to suggest the proper procedure in the administration of the integration as a course of study.

For the administration of the integration as a course of study, two matters are regarded as essential, from the facts of this investigation:

(1) The problem approach should be taken toward any serious consideration of scientific phenomena, in the schoolroom. A limited number of problems have been suggested, but more fruitful problems would be raised by teacher and pupils working together.

(2) The pupil activities in learning the science should bear upon and contribute to the solutions of the problems raised, and will be largely controlled by the problems raised. Experiments in physical science should be regarded as by-activities of the process of learning physical science and not as ends in themselves.

An abundance of material for learning and teaching is presented through the integration in order that appropriate adaptations may be made to individual and local needs. In making such adaptations, the major aims of instruction in the physical sciences should be kept in mind.

The tentative organization as outlined is divided into five major divisions: the celestial sphere, the atmosphere, the hydrosphere, the lithosphere, and the centrosphere. These divisions possess some degree of unity within themselves and are extensive enough to preserve the natural unity of physical nature.

A perusal of the tentative outline will reveal apparent duplication of items; generally, the duplication is more apparent than real. Progressive treatment of processes is provided for by some degree of "spiral arrangement"; in such cases there is the opportunity for the extension of learning. The natural processes pervade all of the spheres; for example, heat, light and electricity are universal phenomena.

While the integration has, for convenience, been divided into five parts the learner should know and appreciate the fact of the unity of science and of nature. For the learning student in the physical sciences it is to be hoped that his pursuit of activities under the head of "physical science" will be for him a single experience, and one which interpenetrates his own experience of living to furnish it breadth and richness.

Logical organization should be looked forward to as an end-result of the use of this integration as a course of study. Facts and phenomena should become mentally tied to general principles which universally operate in the physical environment. The final outcome should be a body of organized knowledge of physical nature and its relations to the affairs of man, a system of interests in physical nature which will add to enjoyment of life and, possibly most important of all, a liberation of the mental processes by development of the scientific attitudes of mind for the intelligent daily living of the average citizen.

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A P P E N D I X

Appendix A

Questionnaire for Investigation of Interests in the Physical Sciences of High School Students and Adults

Town or City ____

State ____

Name of high school ___________________________________

Your name ____

Are you a boy or a girl? __________________________________

What was your age on your last birthday? ________________

Are you a senior or junior in high school? ______________

Check below (x) the sciences in the list which you have studied for at least one-half year:

Physics	( )	Geology	( )
Chemistry	( )	Geography	( )
General Science	( )	Astronomy	( )

What things have you found most interesting in any of the sciences which you have checked above? For example, if you have checked physics, what matters in physics were most interesting to you? Name only one thing, if you can think of only one that was interesting; name two or three things (not more than five), if you are sure that you found them very interesting. DO NOT NAME ANYTHING THAT WAS NOT HIGHLY INTERESTING !

1.

2.

3.

4.

5.

In the same way, mention below some things from the sciences checked above which for you were very dry and uninteresting:

1.

2.

3.

4.

5.

Appendix B

List of High Schools Used in the Investigation of Interests in the Physical Sciences

Florida:	Dade County Agricultural High School, Miami
Kentucky:	Bellevue High School, Bellevue Holmes High School, Covington
New Jersey:	Montclair High School, Montclair
Ohio:	God's Bible School, Cincinnati Hughes High School, Cincinnati Lebanon High School, Lebanon Mason Village High School, Mason Walnut Hills High School, Cincinnati Western Hills High School, Cincinnati Withrow High School, Cincinnati
Washington:	Broadway High School, Seattle
West Virginia:	Brown's Creek District High School, Welch East Fairmont High School, Fairmont Edray District High School, Marlinton Elkhorn District High School, Switchback Elkins High School, Elkins Fairmont High School, Fairmont Huntington High School, Huntington Moundsville High School, Moundsville Parkersburg High School, Parkersburg Romney High School, Romney Triadelphia District High School, Wheeling Union District High School, Dunbar Valley District High School, Masontown White Sulphur High School, White Sulphur Springs

Appendix B

List of High Schools Used in the Investigation of Interests in the Physical Sciences

Florida:	Dade County Agricultural High School, Miami
Kentucky:	Bellevue High School, Bellevue Holmes High School, Covington
New Jersey:	Montclair High School, Montclair
Ohio:	God's Bible School, Cincinnati Hughes High School, Cincinnati Lebanon High School, Lebanon Mason Village High School, Mason Walnut Hills High School, Cincinnati Western Hills High School, Cincinnati Withrow High School, Cincinnati
Washington:	Broadway High School, Seattle
West Virginia:	Brown's Creek District High School, Welch East Fairmont High School, Fairmont Edray District High School, Marlinton Elkhorn District High School, Switchback Elkins High School, Elkins Fairmont High School, Fairmont Huntington High School, Huntington Moundsville High School, Moundsville Parkersburg High School, Parkersburg Romney High School, Romney Triadelphia District High School, Wheeling Union District High School, Dunbar Valley District High School, Masontown White Sulphur High School, White Sulphur Springs

Appendix C

Summary of Interest of 536 High School Boys in the Physical Sciences

Astronomy

Topic	Frequency of Mention
Astronomy	38
Planets	28
Stars	27
Solar system	11
Moon	9
Sun	5
Heavens	5
Universe	2
Heavenly bodies	2
Rotation of earth	2
Astronomical instruments	1

Chemistry

Experiments	64
Analysis	43
Elements	35
Chemistry	25
Atoms and molecules	23
Carbon and compounds	18
Dyeing	18
Problems	17
Iron family	17
Periodic law	15
Applications	14
Equations	14
Gases	14
Acids, bases, salts	13
Formulas	13
Metallurgy	11
Colloids	10
Metals	10
Electrolysis	10

(Frequencies below 10 omitted)

Geology

Topic	Frequency of Mention
Rocks	16
Geology	12
Coal	8
Origin of earth	7
Land forms	6
Volcanoes	4
Erosion	4
Rivers	4
Prehistoric periods	3
Topography	3

(Frequencies below 3 omitted)

Meteorology

Weather	16
Climate	10
Winds	5
Clouds	3
Atmosphere	2

(Frequencies below 2 omitted)

Physical Geography

Geography	7
Maps	6
Rivers	1
Physical Geography	1

Physics

Electricity	252
Magnetism	90
Sound	78
Light	70
Mechanics	63

Physics (continued)

Topic	Frequency of Mention
Fluid pressure	50
Engines	43
Heat	31
Gravity	28
Radio	26
Automobile	18
Atmosphere	18
Forces	18
Motion	17
Levers and pulleys	16
Specific gravity	15
Energy	11
Electrochemistry	10
Experiments	10

(Frequencies below 10 omitted)

General Interests

Experiments	31
Moving pictures	11
Explanations	11
Law and theory	1
Industrial applications	1

Appendix D

Summary of the Interests of 480 High School Girls in the Physical Sciences

Astronomy

Topic	Frequency of Mention
Planets	62
Stars	53
Moon	30
Astronomy	30
Heavenly bodies	12
Sun	11
Solar system	9
Comets	4
Earth	4
Rotation of earth	3

(Frequencies below 3 omitted)

Chemistry

Experiments	89
Analysis	60
Dyeing	30
Acids	30
Metals	22
Foods	22
Soap	21
Equations	20
Oxygen	18
Air	17
Colloids	16
Molecules	14
Gases	14
Halogens	14
Problems	14
Water	13
Atoms	13
Sugar	12
Valence	11
Glass manufacture	10

(Frequencies below 10 omitted)

Geology

Topic	Frequency of Mention
Rocks	14
Land forms	9
Coal	8
Soil	7
Geology	4
Historical geology	4
Rivers	3
Minerals	3
Natural resources	3
Origin of earth	2
Field trips	2
Glaciers	2
Mining	2

(Frequencies below 2 omitted)

Meteorology

Weather	16
Climate	9
Winds	6
Clouds	4
Precipitation	4
Atmosphere	4

Physical Geography

Maps and map-making	9
Climate	3
Geography	2

(Frequencies below 2 omitted)

Physics

Electricity	64
Magnetism	41
Sound	35
Gravity	23
Heat	23

Physics (continued)

Topic	Frequency of Mention
Light	19
Ice manufacture	14
Molecules	12
Mechanics	12
Internal combustion engines	12
Photography	11
Experiments	9
Energy	9
Force	8
Simple machines	7
Density	6

(Frequencies below 6 omitted)

General Interests

Experiments	21
Inventions	1
Explanations	1
Problems	1

Appendix E

Uninteresting Matters for 536 High School Boys in the Physical Sciences

Astronomy

Topic	Frequency of Mention
Astronomy	13
Planets	4
Stars	3
Solar system	2
(Frequencies below 2 omitted)	

Chemistry

Problems	37
Valence	32
Equations	21
Periodic law	20
Ions	17
Atoms and molecules	17
Formulas	14
Colloids	12
Organic compounds	10
Laws	9
Foods	7
Textiles	6
Sulphur and compounds	5
Chemistry	5
Silicon and boron	5
Gas laws	5
(Frequencies below 5 omitted)	

Geology

Soils	5
Geology	4
Mountains	1
Formations	1
Floods	1
Natural resources	1

Meteorology

Topic	Frequency of Mention
Weather and weather maps	17
Precipitation	4
Climate	3
Rainfall maps	1
Clouds	1

Physical Geography

Geography	8
Maps	6
Experiments	1
Physical Geography	1

Physics

Light and light rays	72
Sound and musical sound	70
Heat	30
Forces	26
Simple machines	24
Electricity	24
Gravity	21
Pressure	15
Motion	15
Specific gravity	15
Atomic and molecular theory	14
Atmosphere	11
Mechanics	11
Hygrometry	9
Buoyancy	9
Energy	6
Magnetism	6
Cells	6

(Frequencies below 6 omitted)

General

Problems	5
Recording experiments	4
Metric system	2

General (Continued)

Topic	Frequency of Mention
Definitions	1
Explanations	1
Maps	1
Laws of scientists	1
Experiments	1

Appendix F

Uninteresting Matters for 480 High School Girls in the Physical Sciences

Astronomy

Topic	Frequency of Mention
Stars	5
Planets	5
Astronomy	5
Earth movements	1
Moon	1
Instruments	1
Measurement	1
Eclipses	1
Tides	1
Parallax	1
Distances	1
Figures	1
Origin of earth	1

Chemistry

Problems	52
Equations	47
Formulas	39
Atoms	37
Valence	35
Ions	32
Molecules	23
Periodic law	12
Water	9
Recording experiments	9
Fuels	8
Air	8
Iron and steel	7
Sulphur and compounds	7
Laws	6
Electrons	6
Gases	5

Chemistry (Continued)

Topic	Frequency of Mention
Analysis	4
Textiles	4
Silicon and boron	4
Organic compounds	4
Colloids	4
Solutions	4

(Frequencies below 4 omitted)

Geology

Soils	6
Rocks	5
Topography	3
Water supply	2
Historical	1
Icebergs	1
Waters of earth	1

Meteorology

Weather and weather maps	17
Winds	8
Clouds	1
Climate	1

Physical Geography

Maps and map making	7
Geography	6
Surface of earth	1
Latitude and longitude	1
Natural regions	1

Physics

Electricity	77
Machines	59

Physics (Continued)

Topic	Frequency of Mention
Light	17
Heat	14
Sound	9
Density	8
Magnetism	7
Cells	7
Gravity	6
Energy	4
Friction	4
Atmospheric pressure	4
Accelerated motion	4
Change of state	4
Atmosphere	4

(Frequencies below 4 omitted)

General

Mathematical elements	9
Experiments	4
Definitions	1

Appendix G

Interests in the Physical Sciences of 24 Male Adults

Topic	Frequency of Mention
Electricity and magnetism	15
Light	5
Chemical analysis	5
Motion	4
Origin of universe	4
Rock formations	4
Nature of matter	4
Experimentation	3
Stars	3
Sound	3
Space	3
Climate	3
Minerals	3
Radiant energy	2
Mechanisms	2
Heat	2
Planets	2
Periodic law	2
Carbon and compounds	2
Glaciers	2
Applications of Chemistry	2
Chemical reactions	2
Metals	2

(Frequencies below 2 omitted)

Appendix H

Interests in the Physical Sciences of 83 Female Adults

Topic	Frequency of Mention
Experiments	26
Electricity and magnetism	20
Light	12
Chemical analysis	10
Sound	9
Planets	8
Stars	8
Climate	7
Gravity	7
Atmospheric phenomena	6
Geography	6
Astronomy	5
Geologic periods	4
Machines	4
Origin of universe	4
Industrial chemistry	3
Chemical equations	3
Maps	3
Rock structure	3
Physical geography	3
Soils	3
Medical chemistry	2
Chemical reactions	2
Tides	2
Mathematical problems	2
Transportation and travel	2
Formation of compounds	2
Osmosis	2
Water purification	2

(Frequencies below 2 omitted)

Appendix I

Uninteresting Subjects in the Physical Sciences for 24 Male Adults

Topic	Frequency of Mention
Mathematical elements	17
Atmospheric phenomena	5
Seasons	3
Force	2
Light	2
Chemical theory	2
Terminology	2
Manipulation of apparatus	2
Mechanisms	2
Sound	2
Astronomical instruments	1
Elements	1
Diagrams	1
Electricity	1
Boyle's law	1
Geologic periods	1
Geography	1

Appendix J

Uninteresting Matters in the Physical Sciences for 83 Female Adults

Topic	Frequency of Mention
Mathematical elements	23
Physics	12
Astronomy	3
Chemistry	3
Machines	3
Rock formations	2
Memory work	2
Geology	1
Pure science	1
Air pressure	1
Water pressure	1
Boyle's law	1
Weather	1
Graphs and charts	1
Periodic system	1
Specific heat	1
Energy	1
Motors	1
Experiments	1
Geography	1
Tests for obvious facts	1

Appendix K

Letter of Inquiry Concerning Courses of Study and Instructors

University of Cincinnati
College of Education
November 15, 1928

Dear Sir:

Will you kindly furnish the following information through the member of your department best qualified to give it?

I. The names and addresses of six or more outstanding instructors of the physical sciences in high schools, normal schools, teachers' colleges and universities of your state. Under "physical sciences", please consider: physics, chemistry, astronomy, meteorology, mineralogy, geology, and geography. It is requested that at least half of the instructors be named from high schools.

	Name of Instructor	Name of School	Address
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2.			
3.			
4.			
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6.			

II. Information concerning printed or mimeographed courses of study in any of the sciences mentioned above which may have been developed in your section by the state department of education, city schools, etc. The writer wishes to secure copies of these.

	Name of Science	Author of Course of Study	Where to Get It
1.			
2.			
3.			
4.			
5.			

The information sought in this letter is to be used in an approved research for the doctorate at the University of Cincinnati. The tentative title of the research is, "An Investigation of the Possibilities of a General Course in the Physical Sciences for the Non-Specialized Learner".

Your cooperation and a prompt reply will be most sincerely appreciated. Thanking you, I am

Very truly yours,
Paul R. Morrow
Acting Instructor, College of Education

Name and official position of the person who furnished the information requested:

____

Appendix L

Letter of Request for a Statement of Aims

University of Cincinnati
College of Education
December 1, 1928

Dear Sir:

You have been named by the educational authorities of your state as one among the instructors in the physical sciences unusually qualified to cooperate in a research in your field. This will require but little of your time and energy.

First, will you indicate briefly below what you consider to be the principal general aims in the teaching of physical science to high school students?

Second, will you name several specific aims (objectives) for the teaching of physical science to high school pupils?

Under "physical science", the following are included: physics, chemistry, geology, astronomy, geography, mineralogy and meteorology.

This request is being sent to one hundred of the most competent instructors in the physical sciences in American colleges and high schools. The information sought is to be used in a research for the doctorate at the University of Cincinnati. The tentative title of the research is, "An Investigation of the Possibilities of a General Course in the Physical Sciences for the Non-Specialized Learner". Your kind cooperation will be most sincerely appreciated.

Thanking you, I am

Very truly yours,

Paul R. Morrow
Acting Instructor, College of Education

General Aims

Examples: (1) To develop appreciation of and interests in the physical environment; (2) To acquire an understanding of every-day scientific happenings; (3) To develop the ability to think scientifically.

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Specific Aims (Objectives)

Examples: (1) To understand and use the common air pressure devices and machines; (2) To develop the ability to understand and control the chemical changes which produce light and heat, especially oxidation; (3) To develop the ability to understand and care for a storage battery.

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21.
22.

Name and official position of the person who furnished the data above:

Appendix M

List of Colleges and Universities Whose Instructors in the Physical Sciences Furnished Statements of the General Aims of Science in the High School

1. University of Alabama
2. University of Kansas
3. University of Maine
4. University of Minnesota
5. University of New Hampshire
6. University of Wyoming
7. George Peabody College for Teachers
8. Harris Teachers College
9. Michigan State Normal College
10. Rhode Island College of Education
11. State Normal School, Trenton, New Jersey
12. Western Kentucky Teachers College
13. Sacramento Junior College, Sacramento, California

Appendix N

High Schools Which Furnished Statements of the General Aims of Physical Science

1. Sacramento High School, Sacramento, California
2. Fort Collins High School, Fort Collins, Colorado
3. Technical High School, Atlanta, Georgia
4. High School, Garnett, Kansas
5. Broadway High School, Seattle, Washington
6. Huntington High School, Huntington, West Virginia
7. Roosevelt Junior High School, Fond du Lac, Wisconsin
8. John Marshall High School, Richmond, Virginia

Appendix O

List of Higher Institutions Whose Instructors in Science Education Furnished Statements of the General Aims of Science for the High School

1. University of Michigan

2. West Virginia University

3. Indiana State Normal School, Terre Haute, Indiana