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Scope of Report: The physical sciences were among the last disciplines to become a part of the general education movement in the colleges and universities of the United States. General physical science, now a part of general education, is still in the period of critical analysis and transition. This report involved the study of the history of general education, as it pertained to the physical sciences, and the trends in the development of general physical science programs as a part of the curricula of institutions of higher education. It analyzes the educational needs of the various types of students involved in a general education program in the physical sciences and establishes aims and objectives in terms of these needs. The report discusses the limiting factors in the development of a general physical science course and outlines the major types of programs being presented by various institutions. It presents a proposed program for Northeastern State College, Tahlequah, Oklahoma.

Findings and Conclusions: A great amount of variety exists in the patterns of development of the various programs in general physical science being offered in colleges and universities. However, varied as these programs seem to be, they all have one objective in common: total education for citizenship. Every program seeks to satisfy the educational needs of the students involved.

The development of a general education course in the physical sciences is a curriculum problem unique to the particular institution for which it is being designed. The major factors influencing the development are: the educational philosophy of the institution, the physical plant, the instructional personnel, and the various types of students involved in the program.

To adequately present the physical sciences in a terminal course for non-science students it is evident that more than one semester is needed. The average length of course over the United States seems to be two semesters or three quarters.

ADVISER'S APPROVAL James H. Zant

THE DEVELOPMENT OF A COURSE IN GENERAL PHYSICAL

SCIENCE AT THE COLLEGE LEVEL

By

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THE DEVELOPMENT OF A COURSE IN GENERAL PHYSICAL

SCIENCE AT THE COLLEGE LEVEL

Report Approved:

Report Adviser

Dean of the Graduate School

PREFACE

After teaching science in the secondary schools of Oklahoma for a period of more than twenty years, the author is to join the staff of Northeastern State College in the capacity of assistant professor of science. The assignment for the ensuing year involves the teaching of general physical science. In this capacity the author will be responsible for the development of the program of study to a major extent.

The purpose of this study is to explore the historical background of the general education movement as it applies to physical science, to examine the types of programs now being offered in various institutions, and to develop a proposed program for the course.

The author wishes to express his sincere appreciation and gratitude to Dr. James H. Zant, director of the National Science Foundation Program, for his many acts of encouragement and his constructive criticisms. The author also wishes to acknowledge the many helpful suggestions made by the members of the National Science Foundation Institute. The author is extremely indebted to his wife, Hattie Mae, for her aid in the proofreading and typing of this report and her inspiration throughout the year.

TABLE OF CONTENTS

CHAPTER I

DEVELOPMENT OF THE GENERAL PHYSICAL SCIENCE PROGRAM

Historical Background

Since the turn of the century educators and the lay public as well have been concerned with the quality of the final product of higher education. Prior to that time the general trend in the curricula of the colleges and universities was in the direction of liberal education. With the growth of this concern came a movement to expand the offerings of the various institutions and to provide a much more specialized type of training in many fields not previously included in the curriculum. As a result of this development the number of courses offered has increased many times. One small midwestern college expanded from 67 courses in 1900 to 296 in 1930 and during the same period the liberal arts college of one of the great private universities lengthened its list of offerings from 960 to 1,897.[1] These are in no way isolated cases.

With the increase in the number of offerings came a marked limitation in the area of knowledge a single course could cover. This specialization is characteristic of the society in which we live and no one can refute its claims as to its benefits and advantages to mankind as a

[1]The President's Commission on Higher Education, Higher Education for American Democracy, New York: Harper and Brothers, 1947. p. 47

whole, however, in the educational program it has become both a source of strength and of weakness. Long a part of the graduate school and the professional training levels, specialization has gradually become a characteristic of the undergraduate school and has in many instances made it little more than a training center for further work at the graduate level in one or another speciality. This concentration of learning in a relatively narrow field of education has produced a graduate who, in the eyes of many educators, is not properly equipped to take his place in the entire society of today, even though a recognized specialist in his field. In the report of the President's Commission the following statement is made:

Today's college graduate may have gained technical or professional training in one field of work or another, but is only incidentally, if at all, made ready for performing his duties as a man, a parent, a citizen. Too often he is "educated" in that he has acquired competence in some particular occupation, yet falls short of that human wholeness and civic conscience which the cooperative activities of citizenship require.[2]

This result of specialization in education was apparent long before the President's Commission made its report in 1947. As early as 1918 a Columbia University faculty committee was concerned with one aspect of the trend.[3] Their students were loyally supporting the first world war effort but often did not know why. It was obvious to the committee that the issues of war and peace, of man's nature and destiny, must be presented to the students with greater clarity and challenge. As a result of their work, the now famous course in Contemporary Civilization was

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[2]Ibid., p. 48.

[3]Russell M. Cooper, "What Next in General Education?", College and University Bulletin, vol. 10, no. 8, Jan. 15, 1958.

developed. It must be granted that this committee and this course launched what is today known as the general education movement, a curriculum development which has spread throughout the entire United States. There is scarcely a university or college in the country today that during the years since World War I has not made extensive studies of its curriculum and objectives with the intent and purpose of modification toward a general education program. Great difference of opinion still exists, both between institutions and within faculties, as to the methods to be used to attain the desired goals. Vast as these differences seem to be, there is unity in purpose and desire to develop a general education program that will best suit the needs of the student body and society of today. The validity of this statement is attested by the tremendous amount of literature now available on the subject of general education. Almost without exception the great universities and colleges have conducted studies and published the results of their work, Harvard and Princeton Universities are noteworthy examples. As a consequence of this widespread re-analysis and re-evaluation, general education programs have developed in many forms, particularly in those institutions where the training of teachers is a primary objective.

While among the last disciplines to be effected by the change, by 1940 the physical sciences in most of the liberal arts colleges and teacher training institutions had developed some form of general science education as part of their program.[4] Obviously, these courses

[4]Lloyd W. Taylor, "Science in General Education at the College Level", Science Education, XXIV (October, 1940) 241-49.

are not primarily concerned with the student who intends to specialize, or major, in one of the specific physical sciences, however, in writing on the general physical science program at Haverford College, William E. Cadbury Jr.[5], poses the following question and observation in rebutting the contention that students majoring in a specific science should be excluded from the general program:

Should not the scientist be given the same opportunity to understand science that the other student has? Tacitly, we are inclined to assume that the science student will come to understand science during his study of it - an apparently reasonable assumption, but not necessarily true.

Whatever the ultimate status of the science student, the program is primarily concerned with the non-science student who will find his major interest and field of concentration elsewhere, with the student who needs only a well rounded background education in the sciences. With the tremendous amount of interest that has been kindled in the minds of everyone by the recent achievements in the various fields of science, particularly in the realms of atomic power and space conquest, it is now, more than ever, apparent that scientific information and education understandable to the non-scientist must be made available to everyone.

Herein lies the very foundation of the general education program of the sciences and, unfortunately, its major opposition. According to the report of the Harvard Committee on General Education[6] the principal criticism to be leveled at much of the present college instruction in scienc

[5]William E. Cadbury, Jr., "A General Course in Physical Science at Haverford College", _Science in General Education_, ed. Earl J. McGrath, (Dubuque, 1948) p. 27.

[6]Report of the Harvard Committee, _General Education in a Free Society_, (Cambridge, 1945) pp. 220-22

is that it consists of courses in specialized fields, directed towards training the future specialist and making few concessions to the general student. For the most part such courses concentrate on developing a technical vocabulary and technical skills, and on the presentation of both fact and theory which has been handed down through the years. Basic concepts, historical background, great literature of the subject, and its correlation with other disciplines are all too often entirely absent. The formal general courses in the various science fields usually present only the elements of the science structure. Advanced courses enable the student who continues in the field to compound these elements and by so doing build scientific knowledge and understanding from them. The general student who pursues the field no further than the beginning courses is left simply with the elements and a lack of knowledge as to their use or value.

If this difference between general physical science courses and the traditional general course in the various science disciplines was the only opposition encountered the development of a well rounded general education program in the physical sciences would be comparatively simple. However, along with the basic difference in concepts and objectives, the proponents of general education are faced with a much more serious problem. Due to its nature general physical science requires a special type of teacher, one who is trained in more than one field of science and who has the broad view of general education before him. Teachers of this type are not easily found and as a result the general physical science program has of necessity been staffed from the men trained in the single science fields. Traditionally, teachers of the various disciplines within the science structure of our educational system are very slow to accept any change in the basic presentation of the sciences. A large percent conscientiously oppose general science courses, sincerely believing that such courses will lower the standards now set for their specific fields. They are firmly convinced that general education courses have no place in the science curriculum of higher education, that science is for the specialist only. Fortunately, while this percentage is large, it is by no means a majority and the expansion of general education into the physical sciences is steadily being accomplished.

In his 1950 report, Robert A. Bullington[7] states that of 720 universities and colleges surveyed, 42 percent offer one or more general science courses which cover both physical and biological fields, of these, 50 percent require more than one year for the general student and most require courses in both physical and biological sciences. Of the teacher's colleges reporting, 81 percent offer science general education courses as do 59 percent of all of the institutions surveyed. General education in science is rapidly occupying a position of importance in college curricula, it is growing in prevalence, popularity, and respectability, and is firmly established and widely accepted. Bullington further states that we can confidently expect that in the near future there will be an even greater extension of the courses in American institutions of higher learning.

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[7]Robert A. Bullington, "Summary of a Study of College Science Courses Designed for General Education", Association of American Colleges Bulletin, XXXVI, (May, 1950) 267-72.

Recent Trends

As a means of providing the broad background required by the general education movement, universities and colleges, as early as thirty years ago, began to require at least one course in each of the major areas outside of the students field of specialization for all graduates. In the early years no provision was made for this influx of students who would not be studying beyond the general level. As stated previously, the traditional general courses were not, and are not now, designed for this type of student, particularly in the physical science fields. As a whole, the non-science students did not gain the desired understanding or perspective and thus defeated the purpose of the general education program that gave rise to their enrollments.

In an effort to provide courses which would broaden the educational experiences and background of the non-science student, many colleges and universities developed and introduced the survey courses in science. In the physical sciences these survey courses included material from astronomy, chemistry, geology, and physics along with certain related mathematics. Due to limitations of credit value and time placed upon such courses the educators responsible were faced with only two alternatives: to retain as much as possible of the separate fields covered by the survey course and cover the material at a much faster rate, or to select a smaller number of topics from each of the fields and deal with them intensively. The major portion of the institutions chose the first of these plans of course development, possibly due to pressures from within along with the difficulties encountered in determining just which topics should constitute the subject matter of the more narrow and intensified approach.

In his article on recent trends in science courses, Earl J. McGrath[8] states that these early efforts to remodel courses in science to fit the needs of non-science students were not successful and after a few years were basically altered in some institutions, in others completely abondoned. The principal reason for their failure was their superficiality. The attempt to cover such a large amount of material resulted in the students merely memorizing a quantity of facts with little real comprehension of the underlying laws or any knowledge of the scientific concepts involved. Their one contribution was that they spread the acquired facts over a more broad area of science.

Dissatisfaction with these first attempts at developing better science courses for the non-science student led qualified and interested teachers to experiments with other types of course organization. The results of this experimental approach to the problem manifest themselves in a variety of courses now being offered in various institutions. As shown by the Bullington[9] investigation, these courses may be grouped into four general types according to method of subject matter presentation. (1) more intensive study of selected units from the subject matter areas, (2) a study of selected problems that draw materials from several areas, (3) the historical approach, and (4) the survey type with some modifications. The study also reveals that courses of the survey type are still predominant among the institutions as a whole.

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[8] Earl J. McGrath, "Trends in Science Courses in General Education", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948) p. 382.

[9] Bullington, p. 271.

A more detailed analysis of the course offerings in the general physical science field shows not only this variation in method of subject matter presentation but a corresponding variation in course content. In the twenty-one college and university programs presented in Science in General Education, Earl J. McGrath,[10] editor, seven different approaches according to specific field content appear. The major portion, more specifically nine, include astronomy, chemistry, geology, and physics while five include chemistry and physics only. One adds astronomy to a basic chemistry and physics content, and another presents astronomy, geology, and physics in one course while integrating chemistry with life science in another general course. One institution presents a physics centered course that develops the general or basic concepts of physical science through physics while only recognizing their application to the other physical sciences. Two of the twenty-one combine both physical and biological science into one general course. The remaining two have single science courses, that is courses which, while being essentially one field such as chemistry, present the subject in a more broad and less technical manner than the ordinary departmental general course.

Whatever the type of presentation or the subject matter content, all have one thing in common, they attempt to present physical science to the non-science student in such a manner that it will become a part of his general education and culture and thus enable him to more fully understand the world in which he lives. In writing on What Next in

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[10] Earl J. McGrath, ed., Science in General Education, (Dubuque, 1948), 400 ff.

General Education?, Russell M. Cooper[11], University of Minnesota, sums this up in the following manner:

> - - -But despite these differences, general education courses have much in common. They all seek to provide in a single course an opportunity for students to gain a thoughtful perspective over a broad field of human experience and knowledge, not normally available in a traditional introductory departmental course.

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[11]Cooper, p. 3.

CHAPTER II

EDUCATIONAL NEEDS OF STUDENTS IN THE GENERAL PHYSICAL SCIENCE PROGRAM

Obviously, the basic objective of any program of education is to satisfy the needs of the students participating, that is, to provide an educational experience which will contribute to the development of the individual to such an extent that he will be fitted to take his responsible place in the society of today. In order that these needs may be determined it is necessary that educators look to the students themselves.

It is not the intent or purpose of this study to investigate or take into account the individual differences in needs brought about by inequalities of personality, social adjustment, or home environment. This is properly the field of the educational psychologist and councelor and as such is adequately accomplished. It is the purpose of this study to establish the general needs of the students as a whole. Educational needs vary not only with the major program of the student but with the secondary school background as well. There is little doubt that the selection of a particular field will determine, to a large extent, the general educational experience necessary for a properly rounded program of studies. This is substantiated by an examination of the aims, objectives, and requirements set forth in the program of studies outlined by a major department in any university or college. In addition, unfortunate as it may be, secondary schools are not able to offer equal opportunity for all to enter college with the same background of training and experience. This difference in secondary school opportunity manifests itself in deficiencies of general knowledge necessary to an intelligent choice of major field study. This lack of pre-college educational opportunity is particularly evident in the fields of the physical sciences.

Determining the Needs

In determining the needs of students it is necessary that the type of educational institution first be defined. The General Physical Science course developed in chapter III and discussed in chapter IV of this report is specifically designed for a State owned four year college that has as it's primary objective the training of future elementary and secondary teachers in all fields. While teacher training is paramount, the student body will by no means be limited to future teachers.[1]

The broad educational experiences listed as being desirable in any program of general education are applicable to such a student body as a whole and to the specific field of physical science in particular. Dr. James B. Conant[2] develops this concept very clearly in the first chapter of his book "On Understanding Science".

It is the author's opinion that for the purpose of this report, the students participating in the general physical science program will group naturally into three major categories, (1) those students who, through

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[1]The writer will be an Assistant Professor of Science on the staff of Northeastern State College, Tahlequah, Oklahoma, at the beginning of the 1959 school year. As such, he will be teaching the General Physical Science course.

[2]James B. Conant, On Understanding Science, (New Haven, 1947), pp. 17-40.

lack of previous opportunity, have a need to explore the field to determine interest or to gain background, (2) those who have chosen a major field, other than science, based upon a well rounded secondary school experience, and (3) a special group, not entirely separate from either of the previous but never the less unique, the future teachers of elementary and secondary schools. While the above general classification is essentially the author's, it parallels very closely the one set forth by Leona Sundquist[3] in her article on the program of the Western Washington College of Education. In addition to the broad educational experiences required by any general education program, each of the above groups has certain specific needs peculiar to their category.

The student who enters college lacking in experiences in the physical sciences at the secondary level, with the usual exception of the ninth grade general course, is unfamiliar with the field and quite often burdened with prejudices brought about by conversation with friends and acquaintances who have had unsatisfactory experiences in the more formal general courses in the specific fields such as chemistry or physics. This type of student needs the opportunity of gaining a personal understanding of the scope of the broad field of the physical sciences early in his college career without being faced with the rigors of the more formal general courses. There is also a need to supply the background education lacking in his secondary education experiences.

The student who has made his choice of a non-science major field, outside of the teaching profession, and whose secondary educational

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[3]Leona Sundquist, "Science in the General Education Program at the Western Washington College of Education", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948), pp. 196-97.

background is not lacking in the physical sciences, will be primarily seeking broad cultural experiences as further foundation for his formal education. Students of this type will definitely not be seeking technical training and skills in the physical sciences as normally provided in the more formal departmental general courses. The student who has chosen a major field of study where technical knowledge and skills in one or more of the science disciplines is an integral part is ordinarily excluded from the general physical science program. However, as previously indicated on page 4 of this report, such a student may well be a part of the general program seeking a broad over all view of the physical sciences.

In the preface to the third edition of The Physical Sciences[4], the authors make the following statement:

> With the growing importance of science as a factor in fashioning our environment, and with the extension of science instructinn into nearly all levels of our schools, it becomes increasingly important that prospective teachers secure a basic background in the physical sciences.

While the above statement emphasizes the general needs of all teachers, it is important that we recognize the differences brought about by the grade level to be taught and the degree to which science, as such, enters into the actual teaching experience. The elementary teacher must gain fundamental concepts of the field as a whole and also acquire the basic principles of each of the several physical sciences in order that she may present science in a manner understandable to the children with whom she is working. The elementary teacher is a science teacher, a general science teacher in the true sense of the word, and as such she must be

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[4]E. J. Cable et al., The Physical Sciences, (3d ed., New York, 1951), p. v.

well grounded in the physical sciences as a whole. For the non-science teacher at the secondary level the problem is one of cultural background. With the extreme departmentalization of the secondary school there is little integration of work outside of the traditional fields. The teacher of English or history is little concerned with the mathematics or science program in any direct way. However, there is a carry over into their fields to the extent that students talk and write about science as they fulfill their requirements for reports and theme writing. It is necessary that the non-science teacher have an adequate science understanding in order that they may intelligently guide their students and evaluate their work. In addition to the needs for science knowledge in their classrooms, the average teacher in the secondary schools of this area is called upon to perform the duties of councelor and advisor. With the exception of the relatively large Class A and AA schools and a few smaller ones, no provision is made for specially trained staff members to administer that part of the general program. In this capacity the teacher is faced with the problem of helping the student select his plan of studies and even to a large extent his vocation. A lack of general knowledge of the sciences will seriously handicap the teacher in this vital part of the educational program. The needs of the secondary school science teacher will vary with the student's program of studies. In the average secondary school the science teacher must be qualified to teach general biology and one or more of the physical sciences. Very few schools are large enough to employ teachers for one science field only. If the prospective science teacher intends to meet the certification requirements for more than one of the physical sciences in addition to general biology then general physical science will usually not be a part of his program of studies. If, however, the prospective teacher intends to major in biology or in one of the physical sciences to the exclusion of the others then he will have a need for a general study to provide related background.

In addition to the specific needs of the three types of students set forth above, there are certain broad educational objectives that must be recognized in the development of a course in general physical science. In summing up the trends as brought out by the reports of the twenty-one colleges and universities in Science in General Education, McGrath[5] states that four major objectives are common to all. One, the acquaintance with a representative selection of the basic principles and laws of science, is the central objective motivating the student needs previously set forth. The remaining three are (1) the cultivation and appreciation of the scientific method and the ability to use it, (2) recognition of the impact of science on social and national life and its implications, and (3) meeting the general education goal of knowledge of the history and philosophy of science.

Meeting The Needs

The specific needs of students and the general objectives recognized by educators present a challenge to the general physical science program. It must present a course that cuts across the traditional boundaries of the individual physical sciences and develops the basic concepts common to all. It must develop an appreciation for physical science, its objectives, aims, and methods, and its value in the economic, social, and

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[5]McGrath, pp. 386-90.

cultural world of today. It should provide the historical background of scientific discovery and progress and correlate the advance of science with the development of civilization. Particularly in the teacher's college, it must provide a background of basic scientific fact and a knowledge of the science professions adequate for the needs of the non-science secondary and the elementary teacher.

Furthermore, it must provide a means by which the student not previously familiar with the physical sciences may determine the degree of his interest and aptitude in their direction. While general physical science is essentially a non technical terminal course for the student who is not a science major, it should never be considered a barrier to the further education in one of the science disciplines in the event that a student's latent science interests are awakened.

In the report of The Harvard Committee[6] a further objective of the general physical science program is indicated. The general program must not be construed as being a non-science course, it has an important part in the total science program. The report states the following:

> It frequently happens that the student who concentrates in a science is preoccupied with his specialty to such a degree that he fails to achieve a view of science as a whole and of the interrelationships of the special fields within it. A general education in science needs to be provided for the future scientist or technologist as well as for the general student. One could scarcely insist that all students of history or literature should learn some biology, for example, but that the prospective physicist or chemist need not do so.

General physical science meets the challenge of the needs of the entire student body far better than can the general course in any one of the several science disciplines.

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[6]Report of The Harvard Committee, p. 221.

CHAPTER III

DEVELOPMENT OF THE COURSE IN GENERAL PHYSICAL SCIENCE

The general physical science program designed for any institution must of necessity be developed with certain limiting factors in view. The over all educational philosophy as it pertains to general education, the limitations placed upon enrollment in the course, the time allotment and credit value, the nature of the physical plant and the availability of materials and equipment, along with the instructional personnel will be factors specific to the institution. The type of student body served, their educational aims and objectives as well as those of the institution, and the degree requirements and standards set up by state boards and educational associations, both state and national in scope, are factors influencing the development of the general physical science program in most institutions of the same educational nature. The broad objectives of education, particularly those of general education, pertinent to the program would be applicable to all higher education institutions.

In developing a course satisfactory for a particular institution, the committee or individual instructor will be governed by these factors and guided to a large extent by the published reports concerning similar programs developed in other institutions, particularly those having met with a reasonable amount of success. Before conclusions can be reached concerning the most practical program development, a more detailed analysis of both the limiting factors and the various programs is important.

Limiting Factors

As set forth in the Annual Bulletin,[1] Northeastern State College provides a basic foundation of general education for all students. As a result of a continuous faculty study they have come to believe that all students should participate in certain common experiences during their first two years of college work. It is the belief of the faculty that this general education program must provide the student with experiences which will prepare for living in the democratic society of today. Consistent with this policy of general education, the following specific objective is formulated:

in the realm of scientific training, the student should acquire knowledge and understanding of the natural phenomena, both physical and biological, in his environment, not from the point of view of the specialist or professional, but from the point of view of understanding the natural phenomena in his environment in their implications for human society and human welfare;.[2]

General Physical Science is an integral part of the core program leading to the four types of bachelor degrees conferred.[3] As a part of this core program general physical science is required of all students with the following exceptions:

(a) The student who has completed in high school one unit of chemistry or physics may elect to take four semester hours in other natural science or three semester hours in mathematics in lieu of General Physical Science 104.

(b) The student who is a major or minor in physics or chemistry in his

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[1]Annual Bulletin, Northeastern State College, Tahlequah, Oklahoma. ed. 1957-1958. (Tahlequah, 1957), p. 18.

[2]Ibid., p. 19.

[3]Northeastern State College confers the Bachelor of Arts, Bachelor of Science, Bachelor of Arts in Education, and Bachelor of Science in Education degrees. A Master of Teaching degree is also conferred.

college course, or who for other reason will complete four or more semester hours in either subject, may omit General Physical Science 104 with the permission of his academic advisor.[4]

The general physical science course at Northeastern State College, as approved by the Oklahoma State Regents for Higher Education, is a one semester program with a credit value of four semester hours. The course is designed for the freshman or sophomore year, however, since it is a part of the general core program, juniors or seniors may at times be enrolled. The Annual Bulletin describes General Physical Science 104 as being: "A lecture-demonstration course designed to assist the student to interpret his physical environment. A study of important topics in astronomy, chemistry, geology, and physics."[5]

The college has just recently completed and occupied a new science building, all science departments as well as the mathematics department being located in the one unit. The class rooms are of the lecture demonstration type with large instructor demonstration desks fully equipped with water, both a.c. and d.c. electricity, and vacuum and pressure outlets. Adequate chalk boards and bulletin boards are provided. Supply rooms of the regular departments are accessable and equipment is more than adequate for the general physical science program. Provision is made for the use of projection equipment and the college maintains a large film and strip film library. As a result of this modern physical plant and the availability of equipment, this ordinarily limiting factor may be disregarded almost entirely.

Since its introduction into the curriculum of the college, General

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[4]Annual Bulletin, p. 48.

[5]Ibid., p. 108.

Physical Science 104 has been presented strictly as a survey type course with specialists from each of the major fields conducting the classes for a period of approximately four and one-half weeks. Under such organization the course has been essentially four separate units with little integration between fields or little presentation of the historical and philosophical background of science as a whole. Feeling that these objectives of general education would be more fully met by the presentation of the course by a single instructor with a broad field science training, the Science Committee recommended that such a change be made. Having met with the full approval of the Administration, the recommendation is being put into practice with the fall semester of the 1958-1959 academic year.[6] While consistent with the modern trends in general education, as set forth by McGrath,[7] the advantages of this type of instruction and organization will only be measurable in the results of the course over the next few years.

The educational aims and objectives of students are the factors which largely determine their needs as discussed in Chapter II. As previously stated, meeting these needs is the major challenge to the general physical science program; only by so doing can the course justify its place in the curriculum.

The objectives of the general education program of higher education are too well known by educators to require definition in this study. It is obvious, however, that they will play no small part in the development

[6]The author conferred with Dr. L. H. Bally, Dean of Instruction, and the Science Committee late in June of 1957 and feels that he is expressing the views of both the Committee and the Administration at this point.

[7]McGrath, pp. 399-400.

and presentation of the general physical science course.

Types of Courses Offered in Various Institutions

While the types of programs presently being offered are almost as numerous as the institutions offering them, they may be described for the most part under the four general categories listed on page eight of this report. In the following paragraphs the popularity of the program type, as evidenced by the frequency of their use, in no way determines the sequence of their discussion.

Natural Science 3 of the Harvard University program is an excellent example of the historical approach as a means of teaching general physical science. The course is an out-growth of the experimental course presented by President Conant in 1947 in which he utilized the historical approach and technique outlined in his book, On Understanding Science.[8] The present course is designed to give the non-science major an understanding of the basic concepts, theories, and laws used by physical scientists to explain the major phenomena of the physical world. In distinction from other courses of the physical science program, the course places a greater stress on the historical background and takes into account the philosophical background and implications of the major scientific ideas.[9] From primitive man and nature the course traces the development of science through ancient, mediaeval, and modern history to the present time. The men responsible for the discoveries and developments

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[8]Conant, (Mentor Book Edition), p. 17.

[9]Gerald Holton, Introduction to Concepts and Theories in Physical Science, (Cambridge, 1953). pp. xiii-xviii

of science are presented in their historical surroundings and made to live in the minds of the students. The classic achievements of such men as Copernicus, Archimedes, Newton, Boyle, and others are re-achieved by demonstrations where possible, sound motion pictures are used to supplement where applicable. Outside readings and reports are required on designated topics, but not in excess. It must be pointed out that the historical approach extends to and includes the modern. Nuclear physics: alpha-ray scattering, the discovery of the neutron, the structure of the nucleus, isotopes, artificial radioactivity, and uranium fission are included. The Harvard program is physics centered but includes materials from astronomy, geology, and chemistry.[10]

Colgate University presents a program of natural science composed of two courses, one physical and one biological, both are studies of selected problems from their general areas. The course in Problems of Physical Science is developed around seven such units which are studied intensively. The problems are broad in scope and usually require materials and concepts from the entire field of the physical sciences in their solution. The investigations are not new, in fact the answer may be well known and seem quite trivial to the student at first glance. The sample problem described by Sidney J. French and his co-authors[11] in Science in General Education is one that involves a study of the solar system. In this problem, as in all the others, the particular approach

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[10] F. G. Watson et al., "Science in the General Education Program at Harvard University", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948) p. 99.

[11] S. J. French, C. L. Henshaw, and R. E. Todd, "General Education in Natural Science at Colgate University", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948) pp. 43-48.

used is determined by the problem itself. It is the approach that makes the method worthwhile. The unit is introduced in the following manner:

> The problem is presented in the form, "Does the earth go around the sun or the sun around the earth?" All students have known the answer to this question for many years and they fail to see the point in bringing it up for discussion in a college course. The instructor explains, however, that he and the students are going to take that as a problem to explore according to accepted practices in physical science, that they will assemble their own observations either directly or by quotation from reliable observers, but that any inferences, inductions, hypotheses, or judgments will be made by the students themselves and not borrowed from others.

By skillful leadership the instructor is able to develop the concepts of earth rotation, moon revolution, and the movement of the stars from the observations made by the students. From these primary developments the study progresses until the geocentric hypothesis is developed to such a degree that the students begin to question the universal acceptance of the heliocentric hypothesis. The development continues until the two hypotheses are both plausably explainable from observations and materials collected. At this point the instructor again skillfully directs the development of other criteria that enable the students to draw final conclusions of a valid nature. The problem points up the ease with which conflicting hypotheses can be set up and their relative merits evaluated. Other problems of the course are of the same magnitude and each requires from two to three weeks in its solution. In the seven units materials from all the physical sciences are covered. The basic objectives of the course are (1) to give the student experience in accurate and critical thinking, (2) to develop an appreciation and understanding of how natural science functions to gain its results, and (3) to provide an understanding of some of the important laws and principles of science.[12]

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[12]Ibid., p. 43.

The physical science course at the University of Chicago is one of intensive study of selected units from the subject matter areas. The course is designed to give the student an understanding of his physical environment. The major objectives are (1) to help the student build a unified picture of the physical universe as conceived by modern science and (2) to help him understand, and to give him some training in, the methods of science. In order to attain the first objective the course is constructed around an integration of major concepts from the physical science fields. Critical analysis of the concepts for their method of development serves as a means of reaching the second objective.[13] The units are selected in such a manner that the course progresses from areas more familiar to the average student to the lesser known ones. The first units are those connected with the solar system and basic astronomical observations. In these early units the scientific method is defined, illustrated, and applied. At the end of the units on the solar system a brief formulation of the chief topics that will supply the raw materials for the students thoughts during the term is made: the heliocentric theory, the law of universal gravitation, theories of the earth's interior and the earth's age, the origin of the solar system, the kinetic molecular theory, the atomic theory, the electrical theory of atomic structure, the electromagnetic theory of light, and cosmology. Galileo's experiments and Newton's laws of motion are presented and applied to the solar system and celestial mechanics. The first third of the work is essentially astronomy and geology but leads up to later units from the

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[13]M.C. Coulter, Z. L. Smith, and J. J. Schwab, "The Science Programs in the College of the University of Chicago", Science in General Education, ed. Earl C. McGrath, (Dubuque, 1948) p. 65.

fields of chemistry, physics, and mathematics. The second part of the course develops such units as mechanics, energy and work, electricity and magnetism. The study of heat and change of state leads to the kinetic molecular theory of matter. The atomic theory is developed through the study of chemical action with particular emphasis on acid-base reactions. The electrical theory of atomic structure and the periodic law are developed along with the concept of electron configuration. The last third of the course takes up nuclear reactions, the theory of nuclear structure, and the concept of atomic energy. Theories of light are used to supply further information concerning the structure of matter and are also applied to a further study of the stellar universe and the structure of the stars. The course ends with a review of the methods of science.[14]

The course at the University of Florida comes under the category of a survey of the physical sciences. Since the survey is the oldest of the types of course offerings, and considered by many to be a failure as a means of teaching general physical science (see page 7 and 8), it is important that the history of the program at the University of Florida be reviewed. General physical science became a part of the general education program in 1935. Then, as now, it was a survey type course and like the major portion of the early programs it was unsatisfactory. In an effort to overcome the defects of the program the survey course was abandoned and a program developed around the concept of integration was substituted.[15] From its introduction this program also met with problems

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[14]Ibid., pp. 65-67.

[15]L. W. Gaddum et al., "The Comprehensive Science Courses at the University of Florida", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948) pp. 210-214.

of administrative, instructional, and student nature. The difficulties encountered were of such magnitude that the program was even less satisfactory than the course it replaced. Again a change was made, this time back to the survey course instead of in another untried direction. The present course deals mainly with the principles of astronomy, chemistry, geology, meteorology, and physics. A nontechnical presentation is made where possible and some emphasis is placed on applications to modern life. There are two demonstration lectures and one discussion period each week. The procedures are much the same as in any survey course and the materials are subject only to the limitations of time and materials and the overcrowded classrooms of today. Gaddum and his co-authors have the following to say concerning the course in general:

At present with the survey course, with a few minor exceptions, adverse criticism is practically nonexistent. - - - The traditional nature of the material taught in the present survey course is familiar to administrative officials, faculty members, and students. Moreover, the physical sciences are today in the public eye. Consequently, a survey of physics, chemistry, and so forth needs no apology or explanation.[16]

The program is not the same as the original survey course introduced in 1935. Modifications have been made, principally towards a more thorough correlation between the several sciences and the elimination of the tendency toward superficiality. The 1955-56 catalog of The University of Florida describes the course in the following manner:

C-2 (21-22). The Physical Sciences

- - - The primary aim of the course is to give the student a working knowledge, through the solution of numerous problems, of the physical factors in the environment which affect the development of civilization, with its various cultures. These factors are primarily space relations, weather and climate, landforms, and material and energy relations. The

[16]Ibid., pp. 222-224.

concepts are taken from the fields of astronomy, physical geography, meteorology and climatology, geology, chemistry, and physics.[17]

It is a true survey course in the sense that the fields of physical science are recognized as separate and treated as such.

One other type of program, the single-science course, is important to discuss briefly at this point. Princeton University presents a course that is essentially chemistry but designed to fit the needs and motives of the non-science student. The course is developed around three important stages of a research project which are considered to be desirable goals for a general physical science course. These goals are: arousing curiosity, learning facts, and exercising critical judgment. The content of the course may overlap other fields to a considerable extent, the structure of matter and the kinetic theory are most certainly a part of physics and geology as well as chemistry. However, the instructor who is a chemist will view these topics from the standpoint of chemistry, the physicist will present an entirely different approach. Professor Alyea, instructor of the course at Princeton, has the following comments to make concerning the program: "My preference for the single-science course, rather than the general science course, lies in a realization of the intellectual depth which can be achieved by the single-science course."[18]

In the description of the courses above it has not been the author's intent or purpose to point out or compare relative strength or weakness of the program types but merely to set forth the possible approaches to

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[17] The University Record of the University of Florida, Catalog Issue 1955-56, (Gainsville, 1955), p. 291.

[18] Hubert N. Alyea, "The Single Science Course at Princeton University", Science in General Education, ed. Earl J. McGrath, (Dubuque, 1948), p. 130.

the organization of a general physical science program. The descriptions are purposely short and of a general nature and not intended to be a detailed development of the program. The choice of the particular institution involved in each description was determined primarily by one criteria, the success with which the course is being presented. Each has been outstanding in that respect. Recent scientific achievements and events are influencing the critical thinking of educators everywhere. The increased emphasis on science education will no doubt have its influence on these general education courses as well as the courses in the several specific disciplines. Changes will be effected in the content and intensity of the presentation, however, in view of their success, little change in their type is to be anticipated.

The Proposed Program

In the following development of a proposed program of general physical science, the conclusions concerning the relative merits of the several factors involved, the statement of objectives, the choice of program type, and the selection of specific materials to be included must of necessity be those of the author. It must be understood that this is a proposal, subject to the approval of the Science Committee and the Administration, and may undergo several changes before its formal adoption.

No one program, no matter how complete its development or successful its presentation in a particular institution, can serve as a stereotyped pattern for the program in another institution. Even though the two institutions may be completely parallel in their organization, their administration, and educational purpose, there are fundamental differences specific to each that will greatly influence and modify the development of a general physical science program. The limiting factors set forth in the first part of this chapter (pages 18-20) are specific to the particular institution in mind and will not necessarily be applicable to any other, not even another of the similar colleges within the state of Oklahoma.

The underlying principle of each of the programs discussed in the previous section may well be incorporated as a part of the method used in the presentation of materials in the proposed program. Without doubt, certain objectives of the course can best be attained by the use of the historical approach, particularly those concerned with the development of appreciation and understanding. The basic concepts, common to the entire field of physical science, may best be developed as a study of principles. The study of concepts of a more specific nature will lend itself to presentation as selected problems. Obviously, an objective of the course will be to acquaint the student with the various disciplines to the degree that he will be able to distinguish them, to this end, the survey has its application. The course as developed will be a combination of features from each of the programs discussed but will more nearly classify as a modified survey program.

The specific objectives of the course in general physical science should be: (1) to provide the means of an acquaintance with a representative selection of the basic principles and concepts of physical science, (2) to cultivate an understanding and appreciation of the scientific method and the ability to use it, (3) to develop an awareness of the impact of science on social and national life and its implications for the future, (4) to provide a knowledge of the history and philosophy of science and its importance in the development of civilization, and (5) to instill a desire for further knowledge and/or training in the fields of science.

The introduction to the course should consist of a unit portraying the development of science from the dawn of history to the present. The introductory lectures should present the fact that science was used by man long before he was aware of its existance. The discovery of fire, the development of the first primitive weapons, the perfection of the bow and arrow, and the invention of the wheel were all important in man's progress towards civilization and culture. The historical background of major scientific achievements, present as well as past, should provide a foundation for the study of the basic concepts of physical science today. This introductory historical development should follow the chronology of history but should not attempt to be conclusive. A few well chosen examples from the eras will more than suffice.

The second section should develop the basic concepts common to all the physical science disciplines. This section may be quite extensive since, for the purposes of general education, these basic concepts provide the major portion of the materials of the course. An examination of the course content of beginning courses in physics and chemistry will reveal much duplication in the way of basic concepts. This duplication may be as much as thirty percent and include materials common to geology and astronomy as well. As each new concept is developed its connection with the historical background previously studied should be emphasized. Its relationship to the specific disciplines as well as its importance to civilization should also be established.

Following the development of the basic concepts, four sections, or units, should be presented, one for each of the physical sciences that comprise the course. These sections should include selected materials that will acquaint the student with the particular discipline and develop concepts more specific to the field. As each concept is developed it too should be related to the other sciences in so far as is possible in a non-technical treatment. In every instance historical background and future and present implications should be noted. These four sections comprise the survey portion of the course, as such they must be so developed as to eliminate any tendency towards a broad superficial coverage of the entire field. The materials selected must be presented in such a manner that the student gains concrete knowledge and understanding of the basic concept. This approach necessitates the choice of but a few of the many possible topics.

At the end of the four units on the separate fields, a review of the original principles and laws should be made in order that the student may gain a more complete understanding in view of the additional knowledge developed during the latter units. The course should conclude with a lecture-discussion of physical science in general, its application to better living today, and its implications for the future.

In the development of the sections or units, in the choice of subject matter, in the preparation of lectures and demonstrations, and in the determination of standards, care must be exercised at all times to prevent superficiality. Above all, the program must be so developed as to be a course in science, not a course about science, and as such the students must be expected to do quality work.

Every effort should be made on the part of the instructor to satisfy the individual needs of students as well as those of the class as a whole. Care must be exercised, however, to insure against individual interests of students leading the presentation away from the developed plan. Only through well developed continuity can the objectives of the program be realized.

CHAPTER IV

METHOD OF PRESENTATION - TEACHING TECHNIQUES

The selection of materials to be included in the course is largely the choice of the instructor and subject to the approval of the Science Committee. The list of suggested materials in Appendix A is based upon an examination of six recent textbooks in the field and contains those most commonly presented. The list of textbooks examined appears as a part of the bibliography.

The general method of presentation of the course is defined and limited to a degree by the course description in the Annual Bulletin of the college (see page 19, this report), "A lecture demonstration course - -". This description eliminates certain types of approach used in similar courses in other institutions but does not limit the instructor to any set plan or pattern of procedure for the actual presentation of lectures and demonstrations. The related activities of students, both within the classroom and in the preparation of outside assignments, will be regulated by the instructor in accordance with the policies of the institution.

Lecture and Demonstration

For purposes of organization, the materials of the course should be grouped into sections, or units, and presented as a single or series of lectures. The lecture outlines should recognize the importance of, and provide time for, student questions and observations in appropriate places. It is the author's opinion, in fact a part of his philosophy of instruction, that whenever a student poses an intelligent question on the materials at hand he is entitled to an intelligent answer. If the answer to the student's question is of such a nature that it requires time out of proportion to its value to the class as a whole the instructor should so state, and make arrangements for a time convenient whereby the needs of the student may be satisfied. Techniques of lecture presentation are largely individual in nature and will vary with the instructor.

In the presentation of demonstrations it is anticipated that one period each week will be set aside for major demonstrations of the materials being presented in the lectures. These demonstration periods should be so organized that the demonstrations are started at the first of the period with no time lag due to apparatus and materials not being in readiness. The demonstrations should be prefaced by a clear and concise statement of the intent and purpose, preferably in the form of printed material, and should list questions to be discussed at the end. They should be so designed as to provide time for discussion at their conclusion. The demonstrations may be of any nature applicable to the subject at hand.

In addition to the more formal demonstration periods it is anticipated that the instructor will make use of many simple demonstrations throughout the context of the regular lectures in order to clarify and illustrate. The use of such demonstrations in conjunction with the lectures serves as a means of stimulating student interest.

Class Discussion - Student Participation

Directed and controlled class discussion of pertinent materials is a desirable technique of instruction. Participation in such learning situations provides for training in the art of critical thinking, one of the factors of the scientific method and an objective of the course. Class discussion may well be substituted for formal lecture under certain conditions. As a result of the author's more than twenty years of instruction and administration in secondary schools he has arrived at the conclusion that student participation in class discussion is largely controlled by two factors, student interest and the size of the class. The development of student interest is primarily the responsibility of the instructor. His personality and technique of presentation of materials will determine interest to a major degree. To such an extent is this true that the converse is also possible.

In ideal situations where class size is small, twenty-five or less, student participation is usually spontaneous, easily directed and controlled, and an extremely valuable tool of instruction. As class size increases there seems to be an inverse ratio of student participation, both in the amount and the number of participants. In situations of the latter type it is deemed advisable to curtail such discussion since domination by a few usually results in the destruction of the interest and initiative of the remainder of the class. With the large enrollment anticipated in the colleges in the next few years the ideal situation concerning class size cannot be expected. As a result of large classes, student participation in class discussion will be limited largely to occasional questions or answers to direct query.

Library Assignments - Reports

Realizing the desirability of acquaintance with the contemporary literature in the field, it is expected that library reading assignments will be made from time to time. The number and length of these assignments will depend primarily upon the availability of materials in the college library. Since such reading assignments are made for the purpose of cultivating interest as well as increasing knowledge, a list of desirable reading materials should be made available on an optional basis. Few should be placed in the category of required reading. As a means of determining compliance with the required outside reading assignments, the unit or section tests should include questions on the assigned materials.

As a means of promoting a more detailed study in selected areas of the physical sciences, a report on a selected and approved topic should be part of the term requirements. This report should deal with a topic such as The Scientific Contributions of Lavoisier, The Millikan Oil-drop Experiment, The Bohr Theory of the Atom, Atomic Energy for Power, or The Satellite Program. This list is by no means complete, many other similar topics are available and acceptable. The topic should be of such scope as to require reading from several sources of information in the collection of materials for the paper.

The final decision as to the amount of outside reading to be required, or suggested, as well as the type and quality of the written reports must be delayed until the author has the opportunity to survey the library materials readily accessible to the student.

Visual Aids

A visual aid may be defined as any device used in instruction which imparts knowledge through the sense of sight. In the light of this definition it is immediately apparent that the general physical science course lends itself admirably to the use of visual aids in the instruction.

The entire technique of demonstration must be considered as a use of visual aids.

The definition stated above is not the popular concept of visual aids. For the most part, one type of device, the motion picture, is brought to mind by the use of the term. Obviously the motion picture is a most valuable aid in the presentation of certain types of materials and the development of concepts not otherwise easily demonstrated. "A Mountain is Born" develops the concept of volcanism far better than any other type of approach.

Many other visual aids will be employed in the teaching of the course, slides, strip films, charts, pictures, graphs, and geological specimens. Much use will be made of the "chalk talk" technique. A major portion of the materials of the course will be supplemented by the use of visual aids in one form or another.

Laboratory

The wide variety of astronomical, chemical, geological, and physical equipment necessary to provide laboratory facilities on a student participation basis makes the undertaking almost unsurmountable. In contrast, the equipment is available in the various laboratories of the regular science sections and is available to use for demonstration purposes. Due to the less technical and broader nature of the course, it is felt that the demonstration is the better approach to the problem of providing experiences.

As a result of these factors, formal laboratory work is not a part of the general physical science program. The planned demonstrations are designed to take its place.

Testing and Evaluation of Students

The testing program is an integral part of the general physical science program. Mid-term and semester grades are required in all courses. In order that the progress of the students may be more nearly evaluated, short unit tests should be administered at the end of each section. As previously indicated, these tests will include the evaluation of outside reading requirements, in addition they should cover the demonstrations.

The type of material covered in the specific unit will determine the testing technique. Both objective and subjective tests will be employed, either separate or in combination.

The term report will be due at the end of the twelfth week, it will be evaluated and the results made available to the students, and the score incorporated in the final grade of the course.

The relative value to be placed on unit tests, mid-term examinations, and the term report will be governed by the grading policy of the institution.

CHAPTER V

SUMMARY AND CONCLUSIONS

The integration of the physical sciences into the general education movement has been relatively slow. The retarding factor, for the most part, has been the lack of development of a concept of the need for a science approach for the non-scientist differing from that of the future specialist. Many institutions and science specialists still hold that, while there is need for general knowledge of science among the non-science students, the traditional programs of the individual disciplines are entirely satisfactory. In spite of this retarding factor, the transition is gaining ground with the years and can be expected to continue in its increasing importance and popularity.

Conclusions

The development of a general course in the physical sciences is influenced by many factors not pertinent to the general courses in the separate disciplines. Unlike the introductory course in a single science, the general physical science course must meet the needs of a wide variety of students. General physical science is a terminal type course designed to develop appreciation and knowledge of basic concepts along with an awareness of the social and national implications of the present and for the future.

No one type of course can fulfill the requirements of all institutions. The type of course to be offered must be developed around the student needs and the general philosophy of education of the particular institution. It must integrate itself with the general education program. Its development will be influenced to a large extent by the teaching personnel, the physical plant, and the importance placed upon it by the administration.

In keeping with the increased emphasis now being placed upon science, it is expected that the proposed program will undergo many changes, some before its adoption and others during its presentation.

Recommendations for Future Consideration

In reviewing the proposed program, one major difficulty presents itself. The tremendous amount of material that may be classified under basic concepts of the four specific disciplines included in the course precludes adequate coverage in a one semester course, much of value must be omitted. The general education programs in the physical sciences in colleges and universities of the United States vary in length from one semester to six. The average length of course seems to be two semesters or three quarters.

It is recommended that consideration be given to increasing the general physical science program to two semesters of work with a credit value of eight semester hours. This recommendation is made in the light of this study and in view of the increased emphasis being placed upon the physical sciences at the present time.

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APPENDIX A

SUGGESTED MATERIALS DESIRABLE FOR INCLUSION IN THE CONTENT OF THE GENERAL PHYSICAL SCIENCE COURSE

Historical Background of Science

Prehistoric Man and Scientific "Firsts"
the control of fire - the first tools - the discovery of metals -

Ancient Culture of the Egyptians and Babylonians
first written language 4500 B. C. - first Egyptian astronomy and calendar 4200 B. C. - Egyptian decimal numbering system 3500 B. C. - Babylonian astronomy and the naming of the stars - prediction of eclipses -

The Golden Era of Greece
Pythagoris - Eudoxus - Aristarchus - Aristotle -

The Rise of Experimental Science
Gilbert - Galileo - Boyle - Fahrenheit - von Guericke - Hooke - Torricelli - Huygens -

The Development of Chemistry
"Chemia" - alchemy - the phlogiston theory - Lavoisier - Cavendish - Priestley - Volta - Arrhenius -

Systematic Investigation and Progress
from Archimedes to Zeeman -

Basic Concepts of Physical Science

Weights and Measures
origin - variability - need for widely accepted standards - Metric system - English system - scientific measurement methods -

Energy Utilized and Energy Wasted
work - power - energy - potential energy - kinetic energy - loss of energy - conservation of energy -

Force and Motion
Newton's laws - inertia - linear motion - curvolinear motion - acceleration - action and reaction - gravitation - weight and mass -

Composition of Matter

elements - compounds - atomic theory - molecules - chemical symbolism - atomic and molecular weights - percentage composition - chemical formula subscripts -

States of Matter

solids, liquids, and gases - molecules in motion - the gas laws - adsorption - Avagadro's hypothesis - molar volume and weight - solutions - colloids - crystals -

Behavior of Molecules

number and size of molecules - intermolecular space - attraction of molecules - surface films - surface tension - capillarity - elasticity of solids - Brownian movement - pressure of gases - crystaline structure -

The Structure of the Atom

the discovery of the electron - determination of the electron charge - radioactivity and the discovery of the nucleus - the Bohr atom - general structure of the atom -

Fluids and Fluid Pressure

pressure due to weight - atmospheric pressure - the barometer - pressure transmission - Pascal's laws - "suction" - buoyancy - Archimedes' principle - compressability - Boyle's law -

Simple Heat Phenomena

thermometers - scales - temperature extremes - coefficients of expansion - constant temperature control - heat and temperature - measurement of heat - specific heat - heat of fusion - heat of vaporization - heat transmission - insulation -

Heat as a Form of Energy

energy, not substance - energy of molecules in motion - compression - concussion - friction - expansion of gases - conversion of heat to mechanical energy -

Electrostatics and Magnetism

electric charges - electrically charged objects - forces exerted between charged bodies - the electron, a natural unit of electricity - magnets - forces between magnetic poles - magnetic fields - artificial magnets - the earth as a magnet - the compass -

Concepts of Astronomy

The Earth as an Astronomical Body

size and shape of the earth - rotation - revolution - the seasons - the heavens from different locations on the earth - time - the calendar -

The Moon and Eclipses
motions of the moon - surface - "a rocket trip to the moon - origin of the moon - eclipses -

The Earth's Near Neighbors, the Planets
law of gravitation - Ptolemaic and Copernican systems - retrograde motion - the nine planets - satellites -

Other Members of the Solar System
asteroids - comets - meteors and meteorites - evolution of the solar system -

The Sun and its Radiation
physical characteristics - rotation - sun spots - radiation - corona - atmosphere - spectrum analysis - the sun as a star -

The Stars and Nebulae
distance - motion - light - diameters - variable stars - other forms -

The Milky Way and Extragalactic Systems
form of the Milky Way - constitution of the Milky Way - the exterior systems - velocities of recession and the expanding universe -

Wonders of the Night Skies
the polar constellations - the winter constellations - the spring constellations -

Concepts of Chemistry

Oxygen and Hydrogen
abundance - chemical activity - density - oxidation -

Water
the most common liquid - water as a chemical - uses of water - treatment of water - purification - hard and soft -

Chemical Structure
molecules and valence - metals and non-metals - the stable octet - chemical formulas - chemical equations - simple chemical mathematics -

Carbon
allotropic forms - the oxides of carbon - common fuels -

Basic Chemical Types
ionization - acids - bases - salts - acid-base reactions - pH -

Nitrogen
the atmosphere - compounds of nitrogen - chemical inactivity -

Sulfur
natural occurence - sulfides - oxides and acids -

Chemical Families
the halogens - classification of the elements - the periodic table -

Some Common Metals
ores - metallurgy - alloys - metals for industry - other uses -

The Chemistry of Carbon
organic chemistry - paraffin series - isomeres - olefins - acetylene - alcohols - organic radicals - aldehydes - ketones - acids - esters - dyes - food chemistry - carbohydrates - fats - proteins - complex body proteins - plastics and industrial organics -

Concepts of Geology

Materials of the Earth
composition of the earth's crust - formation of minerals - classes of rocks - composition of the atmosphere, hydrosphere, and lithosphere -

Work of the Atmosphere
weathering - methods of disintegration - methods of decomposition - results of weathering - the wind as a geological agent - deposition, denudation, wind sculpture -

Ground Water
sources - chemical types of ground water - streams, springs, lakes, and geysers - solution and deposition - results of ground water activity -

Running Water
source of running water - run off and types of streams - river systems - sheet wash and valley development - transportation and deposition - results of erosion - results of deposition -

Classification of Streams
young - mature - old

Ice as a Geological Agent
types of glaciers - origin - condition of movement - features of valley glaciers - work of glaciers - erosion, transportation and deposition - prehistoric ice sheets -

Direct Action of Gravity
isostacy - subsidence - mass movements -

Oceans and Lakes
area of oceans - the continental shelf - geological processes of oceans - waves, tides, and currents - transportation and deposition - results of geological processes - classification of shore lines - activities of lakes - size and types of lakes - ancient lakes and their remains -

Sedimentary Rocks
composition - lithifaction - steps in formation - features of sedimentary rock - fossils and rock age -

Vulcanism and Igneous Rocks
vulcanism - magma - formation of igneous rock - types of igneous rock - intrusion and extrusion - volcanism - types of volcanoes -

Metamorphism
heat, pressure, and time - physical change - chemical change - minerals -

Diastrophism
evidence today - evidence of the past - causes - major areas of deformation in North America - processes of diastrophism - folds, joints, and faults - anticlines, synclines, and monoclines - dip and strike - geological maps and their value - earthquakes - the seismograph - mountain forms -

The Interior of the Earth
theory - probable makeup of the core - mass movement -

Origin and Age of the Earth
nebular hypothesis - tidal disruption hypothesis - origin of the atmosphere and hydrosphere - origin of the continents and basins - methods of determining the age of the earth -

Historical Geology
the geological time table - index fossils - geologic eras -

Concepts of Physics

Simple Machines
the lever - the pulley - the wheel and axle - the inclined plane - the screw - the wedge - complex machines - velocity ratio - the efficiency of machines - mechanical advantage - friction - uses of friction -

Sound Waves
origin of sound - speed of sound - the wave phenomena of sound - nature of sound waves - wave length - Doppler effect - harmony and discord - the echo -

Light Waves
history of illumination - light intensity - measuring illumination - laws of reflection - laws of refraction -

Optical Instruments
the eye - the camera - magnification - the telescope - the microscope - the projector - other instruments -

Color and Spectra

Newton and the spectrum - the wave theory and the corpuscular theory - sunlight - spectrum analysis - wavelengths of colors -

Electric Currents

electron flow - electrical conductors and insulators - electricity produces heat - magnetic effect of current electricity - chemical effect of current electricity - electricity produced by heat - electricity produced by magnetic field movement - electricity produced by chemical activity - circuits - resistance - emf - current flow - Ohm's law - measuring instruments -

Communication by Electricity

the telegraph - the telephone - wireless - radio - television - radar - DeForest and the vacuum tube - other devices -

New Tools of Science

the discovery of X-rays - uses of X-rays - radioactive isotopes - the X-ray spectra - natural and artificial transmutation - atom smashers - energy of atoms - cosmic rays -

Nuclear Energy

Einstein and $E = MC^2$ - the atomic bomb - nuclear reactions - power for peace - nuclear reactors - uses of radioactive isotopes -

VITA

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Master of Science

Report: THE DEVELOPMENT OF A COURSE IN GENERAL PHYSICAL SCIENCE AT THE COLLEGE LEVEL

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