

THE NEED AND SCOPE OF A FIRST YEAR GENERAL SCIENCE COURSE.¹

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The term general science as here used is understood to mean a course made up of material from the different sciences brought together and treated in a manner suited to an elementary introduction to science study.

It is not the idea, however, to select bodily certain chapters from the various sciences and form them into a single but desultory course. Let the material be selected with some idea of unity and with some definite ends in view. Let it consist of some of the most fundamental things in science and certain of those principles which have most practical application in everyday affairs, or which are of the most importance in preparing for further science study.

It must not be thought therefore that this is some new field of science recently discovered and introduced just now for the first time. It must of necessity consist mainly of physical, chemical, and biological science, but every effort must be made, however, to give new treatment to the old subjects and to enrich and enliven them by emphasizing the attractive or even spectacular features.

It is true that some of the most common phenomena are the most difficult of explanation, and it is not claimed that *every* important principle can be illustrated in an easy and attractive way to lead the student over some royal road to science; but it is certain that out of the abundance of material enough may be selected that *is* within his comprehension to serve the purpose of the course and amply justify its introduction.

Our science work has been too serious and rigorous, too much of a task. Let it unbend and have more fun. To bring this about is one of the aims of the course in question. If the course does not awaken in the pupils a desire for more science, then it has been improperly taught and has fallen short of its purpose.

It is likely that some one of the sciences should predominate, but opinions differ as to which should be made the basis of the course. The majority of teachers will probably agree that physics and chemistry are fundamental sciences, and that they should therefore constitute a large part of this course. Different teachers

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will differ in their choice of fundamentals. The geography teacher will emphasize that part of physics and chemistry which does most to explain the phenomena of meteorology, climate, soil formation, and related subjects. The biology teacher will select those topics which contribute most to the explanation of the life processes of plants and animals.

It must be kept in mind that young persons are interested not so much in the theory and abstract philosophy of things as in the illustration of everyday phenomena. The material must therefore come largely from the industrial world and the field of household economics.

In any event the course must be *distinctly experimental* and inductive, and it must be conducted in the laboratory where pupils are in the midst of things and are thrown upon their powers of observation. The instructors must be teachers of experience in laboratory work and skilled in demonstration. They must give the class their best efforts and make the experiments speak for themselves. Here more than in senior subjects must the experiments be convincing.

Any course that does not give the pupils some individual laboratory work falls short of its greatest possibilities. However, for lack of equipment and facilities not many schools will be able to give the pupils very much individual work. In either case let the experimental work be qualitative and the amount of mathematical data recorded reduced to a minimum. The course must strive constantly to acquaint the pupil with the everyday things of life and give him an insight into some of the phenomena immediately about him.

I believe, therefore, that the course should consist largely of the material commonly studied in physics and chemistry, and especially of those principles and conditions that find application in everyday common affairs and in other fields of science. For example, diffusion or osmosis is illustrated by experiment as a force or property of matter, but its occurrence as a process of nature is met in botany and physiology. The limewater test is studied and learned in chemistry and the student is prepared to use it as a tool in the study of respiration, ventilation, fermentation, etc. I believe that these important fundamental principles should be studied first by themselves on their own merits and not held in reserve until met in their applied form as occurring in the processes of nature. Some teachers, however, would prefer the other plan and hold the limewater test until needed in respiration. Physiology

would be temporarily put aside and chemistry taken up to the extent of learning the limewater test. Rather let these fundamental principles be learned by themselves and when met in the applied form the student may use them as tools in the same way that he uses algebra in higher mathematics.

At present general science as a course of study is in its experimental stage, and it is found only in a comparatively few schools. It is, however, quite common in New England, especially in Massachusetts, where it is limited mainly to physics and chemistry, and where its aim is not so much to prepare for further study of science as to furnish an elementary course in physical and chemical science complete in itself and resting upon its own merits. At Springfield, Mass., it has perhaps reached its highest development where it is furnished with extensive equipment for elaborate demonstration work.

At Columbus, O., elementary science is studied for the first three months of the first year followed by physical geography during the remainder of the year. The course is mainly physics and chemistry and their applications to physiography, the preparation for which is its chief aim. The course has been more or less varied because of the attitude of the geography and other science teachers, the latter wishing to see it widened in scope and given more time, and the former fearing that it will intrude too much upon geography. It is, however, looked upon with favor by all who have been connected with it to the extent that it is considered a settled and indispensable part of the curriculum.

At Oak Park, Ill., the subject is given an entire year. It is built about a well-selected list of experiments that lead up to physiology.

The University of California has recently recommended general science for the first year of the high school, and a number of schools have already adopted the suggestion.

It will be seen therefore that there is quite a wide divergence of opinion as to what the course should comprise, and as to what should be its chief aim—whether for the science knowledge alone or for preparation for other science study.

In order to be more explicit and put us all on more common ground I beg to offer the following outline as suggestive of a course in general science that may be extended over a year or condensed to half a year.

Outline of a General Science Course for First Year High School.

I. SOME PHYSICAL PROPERTIES OF MATTER.

1. States of matter, constitution of matter. Experiments in impenetrability and weight of air; diving bells, and caissons for work under water.
2. Inertia—Experiments and illustrations. Starting and stopping of the train, collisions, railroad curves.
3. Elasticity and compressibility of air—compressed air fountain, popgun, bicycle pump, riveting hammer, compressed air engine.
4. Porosity of wood, soil, and rock, filtration, oil and gas bearing rocks.
5. Crystallization—blue vitriol, potassium bichromate, alum basket, salt cubes, rock candy. Water of crystallization. Crystallization in nature. Amorphous and crystalline substances—starch and sugar.
6. Diffusion in liquids and gases—osmosis and its application in botany and physiology. Non-diffusible substances—mercury, water, and oil.

II. FORCES.

1. Adhesion and cohesion—water and glass, glass plates, welding.
2. Capillarity—experiments with glass tubes, water, mercury, oil, candle, blotter, lampwick. Creeping solutions—sal ammoniac. Capillarity in botany and physiology.
3. Surface tension—water and mercury surfaces, soap bubbles, oils and camphor gum on water. Globular form—shot, water drop, mercury, planets.
4. Centrifugal force—illustrations and experiments. Sling, flattening of the earth, gyroscope, saucer bicycle track, loop-the-loop, motion of the planets. Industrial applications—laundry and creamery.
5. Gravitation and gravity.
6. The lever principle and its application in the bones of the body.

III. CHEMICAL AND PHYSICAL PHENOMENA.

1. Chemical and physical changes—combustion, solution, filtration, evaporation, precipitation, sodium and potassium on water—alkalies. Elements and compounds. Study of carbon, sulphur, and phosphorus.
2. Acids, bases, and salts. Action of sulphuric, hydrochloric, and nitric acid on wood, cloth, and paper. Litmus and neutralization. Ammonia test for hydrochloric acid. Limestone test. Removal of plaster from floors.

IV. STUDY OF OXYGEN.

1. Generation, tests, properties, occurrence in nature, natural and artificial uses, relation to plants and animals.
2. Necessity of oxygen for ordinary combustion.
3. Function of oxygen in respiration; oxidation and animal heat; oxygen and life.

V. HYDROGEN.

1. Generation, tests, and properties.
2. Formation of water. Explosive mixtures.
3. Artificial uses—oxyhydrogen flame and blowpipe; calcium light, balloons, illuminating gas.

VI. WATER.

1. Electrolysis and testing of the products. Symbols and formulas.
2. Forms of water.
3. Water of crystallization.
4. Boiling point, freezing point, and temperature of greatest density.
5. Expansion of water when changed to ice and the economic value of this.

6. Natural waters—soft and hard. Incrustations in tea-kettle. Boiling of soft and hard water for deposits.

7. Filtration and distillation in the laboratory. Separation of alcohol and water.

8. Water supply of cities—reservoir system, stand pipe system, and engine pressure system.

9. City filtration and purification plants.

10. Air in water. Running and sluggish water.

11. Medicinal waters and mineral springs. Testing of water for iron compounds.

VII. NITROGEN.

1. Preparation, tests, and properties. Comparison of oxygen and nitrogen.

2. Approximate proportion in air and uses.

VIII. CARBON DIOXIDE.

1. Preparation in the laboratory.

2. Chemical and physical properties. Density shown by pouring over candle flames.

3. Occurrence in air and formation in nature.

4. Lime water test and comparison of quantity in the breath and in other air. Carbon dioxide from the combustion of wood.

5. Testing of air in room for carbon dioxide.

6. Effervescence—testing rocks and shells for lime stone. Soda water.

7. Relation of carbon dioxide to plant and animal life. Exhalation of carbon dioxide by animals and of oxygen by plants.

IX. AIR PRESSURE.

1. Air pump and bladder glass. Ground edge tumbler. Vacuum and vacuum cleaners.

2. Water and mercury barometer. Reading of barometer. Pressure curve. Weight of air and water. An atmosphere.

3. Aërial ocean and water ocean. Compressibility of air and water.

4. Uses of the barometer. Aneroid barometer.

X. PUMPS, SIPHONS, AND SPRINGS.

1. Glass tube and piston—water pump. Examination of kitchen pitcher pump.

2. Siphon and uses. Separating milk from cream and water from sediments.

3. Water level, springs, and artesian wells.

XI. BUOYANCY AND SPECIFIC GRAVITY.

1. Floating and sinking bodies.

2. Specific gravity of heavy bodies.

3. Hydrometer and lactometer.

4. Buoyancy of gases—balloons and air ships.

5. Exploration of upper air.

XII. HEAT.

1. Sources.

2. Measurement of temperature—thermometers.

3. Some effects of heat—expansion in solids, liquids, and gases. Force of expansion—steam and its application.

4. Irregular expansion of water and its valuable economic consequences.

5. Change of volume during fusion—bursting of water pipes.

6. Evaporation—effects and uses, cooling by evaporation; evaporators and vacuum pans.

7. Boiling point of water and alcohol.
8. Relation of boiling point to pressure. Culinary applications.
9. Boiling point of solutions.
10. Boiling point in engine boilers.
11. The calorie and specific heat. Comparative time required for heating water and other substances; for example, alcohol.
12. Latent heat of fusion and evaporation.
13. Water as a heat reservoir and effect of large bodies of water on temperature.
14. Land and sea breezes.
15. Artificial cold—solution, evaporation, expansion. Experiments with compressed carbon dioxide. Manufacture of ice.
16. Conduction in solids, liquids, and gases. Davy's safety lamp. Conductivity of the ground. Cotton and woolen clothing.
17. Convection in liquids and gases—Hot air, hot water, and steam heating of buildings—Ventilation. Model of furnace.
18. Trade winds.
19. High and low pressure areas.
20. Radiation.

XIII. HYGROMETRY.

1. Humidity and dew point. Relative humidity, dew, rain, fog, clouds, weather bureau indications, use by pupils of instruments, observations, curves of temperature, humidity and pressure.

XIV. MAGNETISM AND ELECTRICITY.

Needle, earth, compass, frictional electricity, Leyden jar, lightning.

XV. CURRENT ELECTRICITY.

Batteries, electro magnets, electric bell and door bell system, electroplating, electric lights.

XVI. LIGHT.

Shadows, eclipses, reflection, refraction, prismatic colors, and the rainbow.

XVII. HOUSEHOLD SCIENCE.

1. Reading meters and determination of amount and cost of gas, electricity, and water. Testing for quantity of gas used by hot water tank and by a single light. Curves.
2. Testing water for sewage and vegetable matter.
3. City gas systems—natural and artificial gas. Testing pressure by the water manometer.
4. City sewer system—sanitary and storm sewers.
5. Traps and vents in house plumbing system. Siphons.
6. City water supply—reservoir, stand pipe, and engine pressure system. Filtration plants. Fire protection.
7. Methods of heating buildings—hot-air furnace, hot water and steam.
8. Home and school ventilation. Testing for carbon dioxide in the air.
9. Elements and compounds in the human body.
10. Classification of foods—carbohydrates (starch, sugar, glucose), albumins, minerals, water; tests for the different nutrients.
11. Testing nutrients for solubility in cold and hot water—salt, sugar, starch, etc.
12. Occurrence of water in foods—weight before and after drying. Per cent of water in vegetables.
13. Acids, bases, and salts. Litmus tests. Testing of soap for free alkali. Testing vinegar, acetic acid, sour milk, lemon juice, buttermilk, cream of tartar, with litmus.

14. Study and testing of foods for sugar, sulphur, starch, proteids, etc. Changing of starch to sugar. Action of hydrochloric acid on nutrients, Function of the gastric juice in digestion.

15. Stains and their solvents. Use of ammonia.

16. Testing of butter. Specific gravity tests for milk and cream.

17. Study of alcoholic fermentation, yeast, molds, bacteria, sterilization.

18. Meaning of "light" and "heavy" as used in baking. Explanation of "rising." Use of soda and baking powder.

19. Bread raising—yeast rising and milk or salt rising. Alcohol and carbon dioxide.

20. Aluminum culinary utensils—their conductivity and specific heat.

21. Fireless cookers. Relative merits of the hay filled, excelsior filled, and asbestos filled boxes; tested by means of rice.

22. Gas economy—cooking potatoes in gently boiling and in violently boiling water.

23. Functions of the different foods and purpose of cooking starches, sugars, fats, albumins.

24. Food charts and food values.

25. Germination of seeds, relation of temperature, water, and air.

Such in brief is an outline of a proposed course, representing the opinion, however, of only one. Others would have it very different and in fact there would be as many courses as teachers.

The course does not contain new subjects but it is expected that the teacher will adapt the experiments to the age of the pupils and use every effort to give freshness and life to his treatment of the course.

Pupils will have no trouble in learning technical terms when the objects for which they stand are before them. The nomenclature of a science is of no small importance; without it the student is helpless. I do not believe in avoiding scientific terms by using familiar but inappropriate words. It is just as easy to teach perpendicular line as "upright line." The names in science are no harder than the names of flowers with which all children are familiar.

The topics in chemistry are placed early because the pupils are in need of the knowledge of the gases, and because physical and chemical changes must be studied side by side.

The names oxygen, hydrogen, nitrogen, carbon dioxide, etc., are familiar to the pupils before they reach the high school, as they have both heard them used and seen them in print; but to these pupils the terms are merely empty words, names without ideas. Until the pupil has experimented with the gases and seen their properties the terms oxygen and hydrogen are mythical expressions that serve only to mystify and discourage. It is to be regretted that so large a per cent of our high school students graduate utterly ignorant of these simple things of science.

Heat is given considerable attention because of its common importance and the wide application of its principles in geography and the other sciences. The topics in heat are not difficult except those of specific and latent heat, and the only excuse for including the discussion here is their need in the explanation of the effect of large bodies of water on temperature and climate, the cooling effect of evaporation, etc.

The experimental work in home economics will appeal to the girls and do much to give dignity to home labor and to open their eyes to a realization that household affairs should be studied in a systematic and scientific manner. The ignorance of the average high school girl of kitchen affairs is a condition greatly to be deplored.

In conclusion I will summarize the reasons for the introduction of a first-year general science course.

1. To develop early in the mind of the pupil the science habit, *i. e.*, a desire to get at the cause and explanation of things and learn them firsthand—to know as a result of experiment and investigation and not merely by reading the testimony of others.

2. The pupil should not be required to wait until his junior or senior year to get this elementary science knowledge.

3. The preparation that the course gives for the other sciences makes them much more approachable, attractive, and profitable to the student.

4. Less than three quarters of the pupils entering the high school ever reach the junior year and without this course three quarters are deprived of even a glimpse of garden fields of science.

5. As the course greatly enhances the interest in science subjects it has resulted where used in greatly increasing the numbers in the other science classes.

6. The course gives early training in cultivating the powers of observation and arriving at conclusions.

7. With this course in the curriculum some of the subjects of the usual physics course can be given less time or entirely omitted, thus relieving the tension in physics and allowing more time for practical applications of the principles.

8. The laboratories are the most expensive departments of the school and it is not right that their benefits should be enjoyed by so small a number of pupils.