SCIENCE

VOL. LXIII JANUARY 8, 1926 No. 1619

CONTENTS

The American Association for the Advancement of Science:
The Advancement of Engineering in Relation to the Advancement of Science: PROFESSOR A. E. KENNELLY 25
Some Psychological Experiments: DR. J. MCKEEN CATTELL 29
A Suggested Course of Study for Medical Technicians: DR. WALTER E. KING 36
Scientific Events:
Presentation of the Royal Society Medals; The New Museum of Natural History at Yale University; Public Lectures on Scientific and Medical Subjects; Officers of the American Association for the Advancement of Science 38
Scientific Notes and News 41
University and Educational Notes 44
Discussion and Correspondence:
Millikan Rays and the Acceleration of Radioactive Change: PROFESSOR ALAN W. C. MENZIES and C. A. SLOAT. *Insect Toxicology:* F. L. CAMPBELL. *The Requirement of Mathematics for College Freshmen:* DR. HORACE B. ENGLISH 44
Scientific Books:
Hrdlička's Old Americans: DR. C. B. DAVENPORT. *Ross on the Physics of the Developed Photographic Image:* DR. P. G. NUTTING 47
Scientific Apparatus and Laboratory Methods:
A Dilatometer for Measuring the Hydration of Colloids: H. C. HAMPTON 49
Special Articles:
Does Bacteriophage Respire?: DR. J. BRONFENBRENNER. *Inheritance of Anthocyanin in Crepis:* J. L. COLLINS 51
Science News x

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 8, 1879.

THE ADVANCEMENT OF ENGINEERING IN RELATION TO THE ADVANCEMENT OF SCIENCE[1]

THE term engineering is employed with many different shades of meaning. Tredgold's famous definition of civil engineering, which appears in the charter of the Institution of Civil Engineers (London), dating from 1828, commences with the excellent phrase—"the art of directing the great sources of power in nature for the use and convenience of man." In Tredgold's time, there were only two recognized types of engineering—*i.e.,* civil and military. At the present time, nearly forty different branches of engineering have been itemized in technical literature. For the purpose of this discussion, the following broad definition is suggested to cover all types of non-military engineering: *the economic application of the sciences to construction, production or useful accomplishment, especially on a large scale.*

From this point of view engineering manifests itself as the activating principle in the industrial world. Engineering, in this sense, must not only be coeval in antiquity with civilization; but the degree of engineering attainment in any age must also necessarily be an index or criterion of its civilization, judged from the material aspect.

If, as has been claimed by many writers, the acquisition and first permanent maintenance of fire marked the dawn of civilization in the early history of mankind, it would have been the province of the nascent engineering of that time to make a study of the laws of heat and combustion towards the maintenance and distribution of fire in tribal communities. To primitive man, the science of combustion may well have seemed extremely difficult, elusive and complex. The first rational notions on the subject were probably mingled with many errors and superstitions. These psychological stumbling blocks may have hampered and hindered, for many centuries, the attainment of the degree of thermal scientific knowledge appropriate to man's mental and moral development of that period.

Coming down to early historic times in ancient Egypt, we find a considerable increase in scientific knowledge and its application by engineering, confided to a priestly caste. The sciences were assidu-

[1] Address of the vice-president and chairman of Section M—Engineering, American Association for the Advancement of Science, Kansas City, Mo., December 30, 1925.

ously studied, and the knowledge thus acquired was jealously guarded by the esoteric. Considering how large, in the aggregate, are the literature, the statuary and the painting of ancient Egypt that has been preserved to our own times, it is remarkable how few of their scientific records have been found. Taking into account their temples, pyramids, monoliths, canals, ships and metalwork, it is clear that their scientific knowledge was in highly developed application.

In ancient Rome, the keynote of her empire was military power. She explored the sciences mainly for knowledge concerning armaments. Her great system of roads was primarily a system of military communication, for the most part constructed and maintained by the legions, often with the slave labor of conquered peoples. Engineering was chiefly in the hands of military officers, who specialized in various branches of construction. Their scientific knowledge was mainly of a practical kind, and their measuring instruments were relatively crude, but their engineering achievements were considerable, thanks to a national aptitude for practical accomplishment.

Through the middle ages and renaissance, art flourished; but engineering made little progress. Production remained in the hands of crafts and guilds. These developed great manual skill, but scarcely advanced the underlying sciences. Only in canals, shipbuilding and masonry construction, did notable advances occur. Engineering, recognized under that title, was practically confined to military works.

The present era, which is essentially an engineering age, may be said to date from the introduction of the steam engine, and in that sense is only about one hundred years old. The application of the science of heat, in relation to steam for generating power, rapidly changed the nature of production from the individual-worker system to the factory system, augmenting greatly the output of a day's work. This in turn brought new dense factory populations, and also brought the means of supporting them. The so-called industrial revolution, thus started, brought tremendous sociological changes in its wake. Rapid steam transportation accelerated commerce and developed markets. It enabled producers to find sales for their products over a continually enlarged area. A sense of economic emancipation dawned over mankind.

During the middle ages and renaissance, the study of science was slowly advancing in the western world, mainly under the guidance of the universities. This study consecutively followed the growth of mathematics and was seldom directed to engineering applications. The natural philosophers, chemists and mathematicians who lived in the early years of the nineteenth century taught and worked in intellectual regions usually remote from applications to utility. The rapid growth of the steam engine for driving factory machines, in the early years of the engineering era, brought into existence the mechanical engineer, who received his training in the workshop and factory. The mechanical engineer was compelled to study the nature of heat engines and of combustion, the laws of mechanics and the properties of machines. This scientific study was, at first, more or less empirical and unsystematic. In the early days of mechanical engineering, the physicists and scientists were ordinarily so far removed in their experiences from machines and engineering that they saw no way of cooperating with the engineer; while the engineer was so completely engrossed with the practical details of his work that he could see no way of receiving help from theoretical science.

The last few decades have steadily drawn together these two types of men and schools of thought by mutual modification. The constantly increasing scale of machinery and machine production has necessitated more concentrated scientific study of the principles involved. The engineering applications have demanded more scientific knowledge, and the scientists have become more interested in applications. Until about fifty years ago, the initial training of a young engineer, after leaving school, was either by apprenticeship to an engineering workshop, or by being articled, as an assistant, to a practising engineer. It is now recognized that the best training is in an engineering school of a university or technical college, where special study is devoted to the fundamental arts and sciences, followed by technical or applied science in some particular branch.

It is not only in the particular fields of engineering that this close dependence of application upon the sciences has become essential; but also in manufacturing and general production. It may be safely asserted that manufacture, on a large scale, is so closely associated with engineering processes as virtually to become engineering itself. In other words, in order to carry on manufacture economically, on a large scale, the process is practically the same as engineering. There is the same need for scientific study of the principles and basic materials involved, the same need for careful and thorough design, with a view to eliminating waste in material, plant or labor, the same need for experience and skill in the various stages of the work, and the same necessity for careful preliminary estimates of cost, as well as of checking the cost in successive stages.

Every labor-saving appliance in manufacture, and every scientific improvement introduced into its procedure, is a new evidence of the identity between modern manufacture and engineering. A manufacturing community, in modern times of competition and development, is of necessity an engineering community.

Prior to the amalgamation of science and industry in our present engineering age, the advancement of science was made mainly in places where science was studied and taught; *i.e.*, in universities, or institutions of scientific learning associated therewith. Since the amalgamation, however, an increasing share in the advancement of science has been carried on in engineering establishments, *i.e.*, in industrial laboratories, in factory laboratories or in government and state laboratories. A large amount of scientific investigation is nowadays carried on in such institutions, either partly or wholly for economic and industrial advantage. It becomes the duty of scientific societies to collect, correlate and preserve this scientific knowledge, which otherwise might become lost and forgotten. In future, the advances of engineering and of the sciences upon which engineering depends, will be so bound up and interconnected, that whatever gives one a step forward must also give a like impulse to the other.

It would no longer be possible to maintain the huge populations of many large cities in the world, without engineering, *i.e.*, without the continued economic application of the sciences to the supply of the many products those cities require.

Although the needs of utility have in recent years either suggested or demanded numerous scientific researches, it is manifest that many other researches in the sciences are and will doubtless continue to be made exclusively for the truth's sake and independently of any specific utilitarian need. It is only necessary to consider any scientific subject in all its bearings to realize that this must be so. The great science of mathematics, for example, must evidently be greater than the sum of all its applications; so that unless all scientific curiosity as to the nature of new mathematical relations shall disappear, many investigations must continue to be made into branches of the subject that appear to have no immediate applications. Moreover, many cases of scientific research which have been made without any suspicion of applicability have subsequently come to be applied to very practical use. It would seem that the only differences which necessarily separate a scientific research of the basic or non-applied type from one of the applied type lie in the aims and motives of the researcher. In other words, one and the same research, conducted in the same way, will be an applied-science research or a basic-science research, according only to the purpose in the mind of the person who carries on the work.

It is generally conceded that researches carried on for the advancement of science tend strongly to stimulate the imagination. The investigator is called upon, at every stage of experimental inquiry, to speculate upon all the possibilities that present themselves and to set up a new test that may serve to demonstrate which are the actualities and which the unrealities. It is not so generally recognized, however, that the work of the designing engineer also makes special claim upon his imaginative powers in the material realm. Any new project, such as a large bridge, building, railroad or power plant, calls for a careful estimate and design. It has to be completely visualized, part by part, in the mind of the designer, before construction commences. The designer has then, either alone or with the aid of assistants, to realize his plans in two-dimensional drawings. A large project may involve the preparation of many hundreds of drawings, in advance of assembling the materials. All these drawings must interlock and connect in technique and dimensions. Tracings and blueprints from these drawings are then provided for guiding the constructors in their various tasks. The assemblage of design drawings embodies in most new undertakings a considerable amount of invention, imagination and creative work, which the builders proceed to translate from small scales in two dimensions to full-size three-dimensional reality. To the trained eye, a good construction blueprint reveals, under its network of lines, a wonderful image of reality.

In the engineering of building construction, provision is made for the proper conservation of esthetic grace by the profession of architecture. On its artistic side, architecture seeks to foster and promote the art of beautiful building construction. This professional attitude towards art in the engineering of buildings guides public opinion in such a way that graceless and inharmonious buildings seldom escape popular censure. In other branches of engineering, the esthetic quality of the product does not at present find similar professional safeguard. Nevertheless, there is, for each type of engineering construction, a certain somewhat indefinite standard of artistic appearance, below which the designers and builders are sure to encounter hostile criticism. In every country, new types of machines, which are experimental and have not yet established their right to survive, are usually revealed by their awkward appearance. Each country develops, as a general rule, its own type of esthetic standards in appearance, and experts frequently detect, in this way, the nationality of machines and the relative artistic engineering excellence of the nations in which those machines were produced. It is here again that the advancement of science reacts upon advancement in engineering, because the harmony in nature that scientific study discloses tends to guide the minds of those who apply the great principles of nature to the satisfaction of human needs.

Just as the advancement of engineering construction, as, for instance, in telescopes, is constantly tending to the advancement of the sciences—or of astronomy in the case considered—so in return the advancement of science is constantly tending to the advancement of engineering processes. Thus, the precision of geodetic surveying has greatly increased during the last few decades, owing to progress in the sciences of astronomy, mathematics, physics, metallurgy, geology and others. Moreover, the demands made upon engineering design and construction tend ever to become more exacting. For example, it has recently been stated that the new Philadelphia-Camden bridge across the river Delaware is the first in which the supporting towers have had to be given extra strength to withstand the possible accidental impact of an aeroplane.

So close is the present interconnection between science and engineering that the only salient distinction between them lies in their respective relations to economics. Questions of cost inevitably present themselves in the study of basic scientific problems, if only as limitations to equipment; but they are ever present in the study of engineering problems. Indeed, engineering problems call for special methods of accounting and emphasize the importance of determining amortization, depreciation, effective rates of interest and present values of plants. The stocktakings of large-scale businesses likewise tend to become both economic and engineering inquiries.

As the entire civilized world becomes more and more given over to engineering, if only in order to support its large populations, it becomes evident that the conversion of factories for producing utilities into agencies for developing destructive and poverty-making warlike implements is ever easier. The power of science to create in the hands of those who help becomes equally the power to destroy in the hands of those who fight. The world has only to orecently seen how terribly destructive the powers of science and engineering can become in war among the industrialized nations. Modern war is engineering gone mad. This misuse is of course no fault of either science or engineering. If, however, in the reasonably probable advance of both, we are to avoid the utter destruction of civilization by war and the economic servitude of posterity in its wake, we must all unite in building an international organization that shall not only tend to prevent the onset of war but shall also swiftly suppress its first outbreaks. In any such organization, both science and engineering are sure to be powerful elements for effecting control. Under such control, once successfully established, the advancement of science and engineering should surely promote and maintain world peace. Even now all science and its applications are essentially international. No way has ever been found to make science operate exclusively for the benefit of one nation or portion of the globe.

In the basic sciences, the units of measure employed are almost universally the simple units of the international metric system—the meter and the gram—with their derivatives. In engineering and applied science, the units employed have gradually likewise become metric in all parts of the world except in the English-speaking countries, where both the time-honored but cumbersome English and American systems of units persist. Even in the English-speaking countries, however, a gradual transition may be perceived towards the ultimately inevitable international metric system. When the transition shall have become complete, the mutual advances in engineering and in science will be rendered more easy and rapid, through the use of the same language of units. This simplification will benefit science and engineering, not only in this country, but also in all parts of the world where records in our units may extend.

The advances of science and of engineering have thus far always enriched mankind materially. Material production has been greatly hastened; so that the average possessions of men have been increased, or else larger populations have been supported to divide the increase. It is doubtful, however, whether increase of human happiness, beyond a relatively small modicum of possessions, is at all commensurate either with the growth of material wealth or with the growth of population. It seems that while science can largely increase general comfort and prosperity, it can, at present, insure but little increase of happiness and contentment. Whether this must always and inevitably be so, is debatable, and depends to some extent on our definitions of science. In any case, we must turn for help to moral and spiritual sources of happiness, if we are to continue to become increasingly indebted for material wealth to the scientific revelations of the interpretable universe. At present, it appears that advancement in the power to enjoy and give contentment is more difficult for us collectively to acquire than advancement in the power to secure material benefit through science and engineering. In the discovery and maintenance of these uplifting philosophies, the calm and contemplative orient has surpassed the tense and restless occident.

It is generally admitted that the study, either of the sciences or their applications, tends to produce in the mind of the student a sense of humility and a respect for truth. Indeed, it is not strange that habits of seeking or applying scientific truths should engender habits of faithful thinking. In this respect there is encouragement in the belief that the tendency of the present engineering age is, on the whole, towards accuracy of reasoning and precision of thought. Scientific ideas may tend slowly to dominate over irrational and irregular thinking. A casual review of general literature over long periods of time seems to show that as science has advanced irrational and superstitious ideas have dwindled. The concomitant danger, however, lies in the occasional ravages of erroneous pseudo-scientific doctrines. A plausible but false doctrine, that masquerades as a scientific proposition, may produce more harm in a scientifically disposed world than a flagrantly immoral popular belief of a clearly irrational character. The responsibility for making unguarded statements that are unsupported scientifically thus rests increasingly upon all speakers and writers.

In the development of the applied sciences, a constantly increasing demand devolves upon the underlying basic sciences. In the prehistoric times of primitive engineering only the simple rudiments of the underlying sciences may have been involved. In the ancient Egyptian and Roman days, engineering must have demanded a closer study of mathematics and physics for support. Since, however, the dawn of the present engineering age, much more knowledge and research have been demanded in a long list of the branches of basic science. Invention is always needed. But whereas in past times, inventors, if they had the requisite talents, did not need much scientific knowledge, at the present time, the successful inventor has not only to be endowed with inventive ability, but he must also be well versed in basic science. It appears that in the future this demand for basic scientific knowledge, as a prerequisite to applied-science progress, will continually increase.

The leadership of the ancient world rested mainly upon physical force. The trend of the more recent past through the present, towards the future, is for world leadership among the nations to rest mainly upon science and its applications. Already the progress of engineering is hampered and thwarted in many directions by lack of advance in the basic sciences. It is to these that national attention should be directed, for the progress of knowledge that benefits first the nation in which it is made, and later all the other nations. If only in the interests of applied science, the advancement of basic science in America should be stimulated and fostered. Support for applied science is likely to be forthcoming from the industries themselves; but support for basic science is more difficult to secure. The national importance of this is so great that the need should be made widely known. An effective way to stimulate advance in the science in this country would be to secure permanent endowment for a suitable annual prize, to the most notable contribution each year, in each section of the American Association for the Advancement of Science. This official recognition of scientific achievement would stimulate and encourage researches in all sections. There is no reason to fear that such scientific progress might be practically valueless. Useless scientific knowledge is now a contradiction in terms. Moreover, aside from the question of immediate versus future application, the patient earnest study of truth, in those parts of the universe that are attainable to us mortals, constitutes the noblest quest with which we are yet acquainted.

A. E. KENNELLY

HARVARD UNIVERSITY

SOME PSYCHOLOGICAL EXPERIMENTS[1]

II

THE age curve is of fundamental interest for psychology. Thus, for example, a child can learn to pronounce his own or a foreign language best at the age of about three years; there is then a drop and after about twelve years he can not learn correct enunciation. Perhaps a boy can learn to ride a bicycle best at the average age of ten, to drive a motor car at the age of sixteen. Our most original ideas probably come in the early twenties. Some of us may hope that the curve for forming correct judgments rises at least to the age of sixty-five. Our primary school system consists largely in trying to teach children, with much labor and resulting stupidity on the part of both teacher and pupils, mathematical relations a couple of years before the organism is ready and could respond to them without effort. Then, as this is the easiest subject in which to examine children, they are promoted from grade to grade mainly on performance in arithmetic without regard to individual differences in other kinds of work.

The Binet-Simon scale, first used in 1905 to diagnose subnormal children and in 1908 to measure the mental age of children, developed in this country by Dr. Goddard, Professor Yerkes, Professor Terman and many others, together with the group tests that we owe to Mr. Rice, Dr. Courtis, Professor Thorndike and many others, have been of untold value to our schools and to the children who are the ultimate

[1] Address of the retiring president of the American Association for the Advancement of Science, given at Kansas City on December 28, 1925.