Report of the
NEW ENGLAND ASSOCIATION
of CHEMISTRY TEACHERS

The Scientific Method as Applied to Different Fields of Education[1]

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WE ARE ALL seeking truth. Philosophers say we can find truth, but it is hard work. Truth should be sought in every possible way and one of the ways is by study. Study develops man's intellect, the most human part of him, and gives him a deeper and fuller sense of the dignity of the human person. This development of man in the wholeness of his natural and supernatural being demands that man make the most of his powers—his creative energies, his life of reason; it demands that he labor to make the forces of nature his instruments for freedom, and finally that he learn to share the life of God.

Striking evidence of such growth is not found in society today. Instances of unhealthy mental conditions abound. Honesty and integrity are not conspicuous—rather, is the art of lying displayed on our billboards and in our newspapers and magazines. A study of propaganda furnishes many more examples of dishonesty and falsehood. Our rulers, legislators, business men, professors, philosophers, and scientists should give evidence of a persistent urge for the truth. Instead, ignorance and a prejudice which begets ignorance are far too widespread.

We are told this is a scientific age, that science is to blame for the world of today, that it has implemented the war either consciously or unconsciously. True it has supplied the materials, but not the "will to kill," unless it be by a sin of omission. As an educational tool the scientific method has not been used to its fullest extent and this failure to "get it across" to the majority of the students passing through schools and colleges today may be the sin of omission and may be a reason why the country as a whole is not looking forward to sitting around a "peace table" with any measure of assurance that all will be well.

The main contribution of science in this crisis is not the practical applications, the industrial and technological products of the various laboratories, important as these are, but the sceintific method and the scientific attitude, which should permeate every field of endeavor. Truth is conformity of ideas with reality. And what is the scientific method but a method of deriving ideas from reality and a constant checking of ideas with reality? First, one must find a problem to be solved, define its terms, limit its scope so that extraneous factors are under control, and proceed with accurate observations and classification of facts. Second, a process of analysis, discrimination, finding relationships, and reasoning validly leads to the organization and formulation of an explanation or a theory. Third, there is careful experimentation to check the truth or falsity of the generalizations, and fourth, the theory is confirmed or rejected.

Such a scientific method applied consistently to everyday life would demand another way of living, an honest facing of the facts, a substitution of reason for emotion, freedom from domination of fear, ignorance, prejudice, and superstition. The application of this method to daily life would further demand a realistic type of thinking which requires effort to distinguish truth from error, evidence from opinion, and requires also the suspension of judgment until facts are known. Thus, problems would be recognized, faced, and solved.

The scientific method as a tool was never meant to be the sole possession of the science department. Answers to a questionnaire given to members of a college faculty showed that it can be and has been used in every department.

In an organic chemistry class of eight in the second term of the course, the laboratory manual was scrapped. The class wanted to synthesize rubber. They didn't come out with a rubber tire, but with something much more valuable. They had to plan each step, consider the possibility of carrying it out, the time, the chem-

[1] Abstract of a paper presented at the 220th meeting of the NEACT at Hillyer Junior College, Hartford, Conn., March 6, 1943.

icals on hand, and the cost. All this developed responsibility, initiative, and resourcefulness. They learned to use the library in searching for and comparing methods. They used many types of apparatus. They saw processes (distillation, extraction, etc.) in their proper perspective as means, not ends. They discovered how careless following of procedures, even in apparently insignificant details, could effect a yield. Besides the rubber project, these students were allowed to choose the other experiments for the term. It was noted that they chose about the same type of experiments as would have been outlined for the course and in most cases they were chosen from the text (not the manual) because, from the discussion there, they had become interested and wanted to do the experiment. They did not do as many experiments but carried through longer and much more difficult work, and learned much more chemistry. Here are some of the students' comments: "I liked it because you were on your own—shows what we can do without specific directions." "You have no interest in what yields the others are getting, as in experiments from the manual. It is more fun and interest makes you do your work better."

Next is an illustration of how a teacher of history applies the scientific method: (1) By getting students to go to first sources. For example, the ancient history class read Thucydides, Herodotus, and Xenophon. The American History class used documents, such as Force's Archives. They visited legislative sessions and hearings. The Contemporary Affairs class read "Mein Kampf" and the "Communist Manifesto." (2) By teaching students to see all possible sides of a question. The American government class conducted weekly forums prepared and presented on current topics. (3) By facing facts. Attention was given to rationalization, wishful thinking, and oversimplification. (4) By requiring specific information and definite knowledge. Basis for statements, evidence, arguments, and rebuttals must be supplied. (5) By analysis of propaganda found in newspapers, on the radio, and in the movies. (6) By developing critical attitudes. Students were asked and wanted to choose their text from four texts presented. Each one was required to state the standards upon which her independent choice was based. The choice of the majority was adopted.

Last year in biochemistry, a term paper on some phase of blood chemistry was assigned. Two students asked to be allowed to substitute a laboratory study for the paper and presented eminently satisfactory scientific reports of the work. After an embryology course, a student brought back a dozen hen's eggs to incubate so that she might follow the course of development of the young chick day by day. The experiment proceeded successfully through the different stages but ended disastrously not once but twice. She set about solving the problem of her failure and is now about ready to repeat her project with various mechanical difficulties under better control. This is not a class project or one which will add credits to her record, but is, for just that reason, a better indication of a truly scientific attitude on the part of the student. All these students took the attitude that although a term paper as such is easier and more quickly done, a problem offers a challenge and its successful completion gives not only a sense of satisfaction but also the experience of an intellectual pleasure in a well-ordered, carefully thought out piece of work.

The home economics department gave samples of home projects, chosen, carried to completion, and evaluated as examples of the scientific method used as completely as possible in such work. One student selected planning meals and marketing for one week. She had done this at home in Vermont before, but the problem was to do it in Florida where the family was living during the winter. An inventory of the food on hand was taken. After examining newspapers and magazines, and after careful inquiry to find the location of the markets and the best "buys," the menus for the week were prepared and an efficient market plan outlined. Experiments were made with the menus and market plan and both were revised. The accounts were kept and there was a balance of about 30 per cent of the budget. The reason for this and for a departure from suggested division of expenditures was sought and found to be due to the location and the season of the year.

In a course in statistics, the students were asked to find a problem in any one of their other courses (economics, business, sociology, science) in which they were interested and to apply the statistical methods learned in solving it. For example, from a paper entitled "A consideration of an equitable basis for representation of towns of the Lower House of the General Assembly of Connecticut" in which a statistical study of population, areas of towns, grand lists, and numbers of representatives of towns was made, the following conclusions were drawn: (1) Connecticut is an industrial state; (2) use of the grand list to determine economic importance of the towns as a basis of representation is inadequate and impractical; (3) a change in the present dual population-area method of determining representation is needed; (4) population remains the best method of weighting the importance of the towns in determining representation.

Child-study students enter the course with many subjective attitudes and prejudices concerning child growth and development. Where these can be discovered early in the course a student finds it possible to investigate such an attitude. One student who claimed to be without antisemitic antagonism declared she could determine Jewish backgrounds of nursery school children by a study of their behavior. She was assisted in the setting up of the problem and guided in the necessary techniques of observation and analysis. She failed to prove anything about the children, but she did discover her own prejudices. Her list of Jewish children showed she had classed as such all the

aggressive children and thus had included many who were not Jews and excluded the shy, retiring Jewish children.

This assignment in introductory philosophy was used to further an understanding of the scientific method: "Use scientific method to prove or disprove the theory of the mechanistic materialist." Term paper subjects were chosen to induce students to use scientific methods in collecting data. For instance, the term paper, "My search for truth," was to be the account of a day by day effort to reach truth by use of the scientific method.

The most extended use of the scientific method in an English survey course of writers of the western world was in connection with the study of Aristotle's theories in regard to tragedy as set forth in his "Poetics." The first step was to abstract from the text of the "Poetics" the criteria Aristotle had established for tragedy. The chief plays of Aeschylus, Sophocles, and, to a lesser degree Euripides, which Aristotle had used as a basis for his generalizations, were then examined for evidence "in concreto." The problem was now posed: to what degree has representative tragedy since Aristotle adhered to the criteria set forth by that philosopher? Beginning with the work of Seneca, and ending with the work of O'Neill, each student now chose outstanding examples of tragedy in all periods offering such examples, applied to each the criteria of Aristotle (and no other critical standards), noted carefully the correspondences, and departures, classified her findings and reasoning as validly as the evidence permitted, offered generalizations as to: (1) the degree to which post-Aristotelian tragedy has adhered to the criteria set forth in the "Poetics"; (2) the periods in the history of literature characterized by (*a*) the closest adherence, (*b*) the greatest departure; (3) the specific standards most frequently accepted as valid by the later generations; (4) any criterion universally accepted.

In a class of poetry the students are developing a fearlessness of appraisal, an intellectual approach to analysis, and other characteristics which belong to the scientific attitude. The whole matter of arousing and training the mind for critical work in literature can be seen to be completely consonant with the scientific method and, if successful, to produce the same desired results.

This study of the scientific method at college level is not complete. Some departments where problems have been handled scientifically have not reported as yet. For example, sociology students do field work, make case studies, and at the beginning of their senior year choose a problem for investigation. The home economics department has not yet reported on the managing of a household for six weeks during senior year, nor on the many textile experiments, such as investigating the effects of different cleaning fluids, and nutrition experiments on white rats and guinea pigs.

But enough has been shown to indicate that a great deal can be done to foster growth in scientific method at college level and, from reports of the child study department, at secondary, elementary, and primary levels as well. A student making a study of how children think in the pre-school period of their lives compiled an interesting account of thought processes, the beginning of the scientific method.

A three-and-a-half-year-old said to his teacher, "I can walk faster than you." The teacher said she didn't think he could although she believed he was a fast walker. After a few minutes play the child returned to the teacher saying, "Can you walk faster than a horse?" The teacher said, "No." "Well, I can," said the child, "so I can walk faster than you."

Again, a group of four-year-olds speculating on why the horses went into the barn every day at noon admitted generally that the horses went in to get gas. This isn't so funny as it sounds. Is it not the dawning power of generalization in the child?

As science teachers, we are interested in scientific growth and development in all departments and at all levels from the little one in the home to our college graduate who goes forth to influence and make the destiny of our country. We are interested in the perfection of society, in the laborious search for truth. But we must be more than interested. We cannot evade the responsibility for an inertia which fails "to do and to teach." We must abandon scientific aloofness. The world of today does not need most our material technology, it needs the spiritual values of science. If we could influence a few more to think intelligently, examine evidence critically, and check ideas with reality, then we would be educators "in deed and in truth."

OFFICIAL BUSINESS

220th Meeting—March 6, 1943

Hillyer Junior College

Hartford, Connecticut

The members of the Association enjoyed the 220th Meeting as guests of Hillyer Junior College, which is the education division of the Hartford Y. M. C. A. After a brief address of welcome by Alan S. Wilson, Director of Hillyer Junior College, the following papers were presented: "The scientific method as applied to all fields of education," by Sister M. Consilia Hannan, St. Joseph College, West Hartford, Conn.; "Hydrochloric and sulfuric acids as catalysts in certain hydrolytic reactions," by Professor Vernon K. Krieble, Trinity College, Hartford, Conn.; "Aircraft fuels and lubricants," by Mr. E. A. Ryder, Pratt and Whitney Aircraft, East Hartford, Conn.; and "Spectrophotometric analysis," by Dr. M. G. Burford, Wesleyan University, Middletown, Conn.

At the brief business meeting, the Membership Committee announced the election of Mrs. H. F. Fenerty, Lincoln School, Providence, R. I., to active membership.