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EDUCATION BY AUTHORITY OR FOR AUTHORITY? ARE SCIENCE TEACHERS TEACHING SCIENCE?[1]

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I FIND it rather difficult to discuss the teaching of science as I wish to discuss it without first discussing some of the more general aspects of teaching and education. So perhaps by way of introduction we should first consider the question as to what constitutes an education and what are to be its aims. This may be a controversial topic, but it is necessary to formulate at least tentative objectives before one can effectively discuss attainment or methods.

With some of the many subjects taught in the elementary schools, as well as in the trade and technical schools, the answer as to purpose and accomplishment may seem relatively obvious. The pupil learns to read, to write and to do simple problems in arithmetic. He obtains information and rules that he uses in daily routine. But in increasingly large numbers, young people are taking high-school and college subjects for, as they say, their "general educational or cultural values," not fitting themselves specifically for a vocation or trade. But why should a high percentage of the population study higher mathematics, ancient languages, modern languages, English literature, history, economics, chemistry, physics, geology, botany, zoology, etc.? Are these subjects or fields of general educational or cultural value? If so, why? And are they of equal value? Is a man educated or cultured because he has spent one to four years in studying or can read or speak a half dozen or more languages? Is he educated because he can solve intricate problems in mathematics, or can determine the chemical composition of a rock or a plant, or can synthesize some important compound? Is he educated because he can

[1] Condensed from the address of the retiring president of the American Society of Plant Physiologists, at Richmond, Va., December 28, 1938.

accurately describe the structural minutiae of a cat or a corn plant?

To some people an individual is considered educated if he has had a certain amount of formal schooling in any subject. Each of us, however, can call to mind several individuals who have had extensive and intensive formal schooling, but whom we should not consider as soundly or broadly educated. Probably no one subject is peerless as a subject for educational purposes, because we can find no relation between the subject of one's specialty and what we might consider his standard of educational attainment.

I doubt if we can agree as to what subjects are best for a general education, or even as to what constitutes an education; unless we agree that mere attendance at school for a given number of years will insure an education. Nevertheless, let us try to formulate an objective which, although it may fall short of what one might wish to include, still is not beyond hope of attainment. I think we can agree that the training of a person, if he is to be considered broadly educated, should be such as to give him understanding of himself, of the world about him and of his relationship to that world. It should give a foundation for further advancement and an ability to appreciate values and distinguish between the true and the false. It should prepare him to live with satisfaction in the present world; to meet without panic and without prejudice various problems as they arise; and he should be able not only to grow with, but also to help in improving, a growing world and changing civilization.

Our present civilization has developed the extensive school system which to-day gives an opportunity for large numbers of individuals to take advantage of the knowledge and experience of their contemporaries as well as their predecessors. In this school system are offered courses over a wide range of subjects and at levels suited to almost any age and ability. In the secondary schools, colleges and universities there are made available to students a vast array of courses for giving special training in almost any field one could wish to study. It seems surprising, however, that, of the students from these schools, so many of them seem to lack just what one would expect educated people to possess. They have such strong prejudices, political prejudices, social, religious, class and racial prejudices. They are so easily influenced and controlled by slogans, by propaganda and by dogma. They are so lacking in critical judgment, in poise, and so little given to looking for, and critically evaluating the evidence on both sides of a question. In fact, it often seems that people who have had a formal education are likely to have stronger prejudices, are less eager or less willing to hear both sides of a question than are those with less schooling. They are often more smug, more self-satisfied and less reasonable. This may be due to the fact that their training has made them complacent by giving them a false confidence and over-assurance. It has failed to make them more cautious and more humble. In short, it has failed to give them understanding. That it has failed in giving understanding is indicated by evidence of many sorts. For example, large numbers of our people, although they have literally spent years in school and are also exposed on all sides to developments of astronomy and related sciences, and have thus had opportunities far beyond those available even to the most privileged of a few generations ago, yet they believe in astrology and are swayed by the most impossible beliefs and superstitions as regards the influence of the stars on their individual lives. It is a disgrace to our civilization that it has gone so far in science as to develop the radio, and yet one can hear over this same radio the drivel of so-called "professors of astrology" whose pronouncements are on a level of thought comparable to that of primitive peoples or those of ancient or medieval times who had no contact with scientific method or thought.

It seems strange that in this day and age states can pass laws against the study or teaching of evolution: that other states can pass laws dictating what can be presented in books on history (to say nothing of the complete control over all fields of teaching as is practiced in many foreign countries); that laws are passed prohibiting the discussion of communism in schools: that states with the richest and perhaps the best-developed school systems in the world can pass or nearly pass ridiculous and even vicious laws. In the past two decades legislatures have passed or nearly passed laws against sanitation, against vaccination and against scientific investigation with living organisms. In such states with these richly supported school systems there are strongly organized groups of Anti-vivisectionists, Anti-evolutionists, Theosophists, Faith Healers, New Thoughtists, etc. It is my impression, though I have seen no data, that a high proportion of the people that make up these groups are from the so-called "more educated" classes. There are some grains of truth in the propositions of most of these organizations, but their adherents go to the greatest extremes and appear entirely lacking in understanding and in common sense, in judgment and in ability to evaluate critically. They fail to distinguish truth from the partly true or the false, to recognize values; and yet these people, many of them, have had the opportunities of higher education, including college and graduate schooling.

Not many years ago a professor in a university of high standing, a professor in a science department, let his son die of appendicitis without even consulting a physician. He knew there was something wrong

with his son, but he had become a Faith Healer. When asked by a doctor why he had not called in a physician when his child was in such a condition he replied, "Even you doctors sometimes lose your cases." There is no doubt but that one's mental attitude may have a great influence on his health, but one must use judgment as to when certain rules of procedure apply and when they are not adequate. This man's education, although it was in a so-called science subject, had not gone deep enough to enable him to recognize that one individual can not cure appendicitis in another by thinking high thoughts or by refusing to recognize acute and obvious signs of physical ill-health. It is true of course that many individuals imagine symptoms where none exist and may thus, through nervous control, actually bring on physical disturbances. But why go to such extremes? An educated person should be capable of using judgment and not merely blindly follow rules. Another professor with a national reputation in the field of economics, one who has had a fair amount of training in science, not long ago made the statement that "Vaccination and serum treatments are all bunkum." Within a few years I have received chain letters from two men, each holding the degree of doctor of philosophy. Each letter promised good luck if forwarded, and bad luck if the chain was allowed to be broken. The superstitious fears of these doctors of philosophy made them uneasy or perhaps even afraid to break the chain. No doubt each of you can think of comparable cases of individuals who have had extensive schooling but who seem to fail to show understanding or even "common sense." The medicine man, the believer in witchcraft and the voodoo priest are practicing right in our midst to-day, although they call themselves by more high-sounding names.

Is this failure of so-called educated people to come up to the standards we wish and have a right to expect, is this due to the weakness of the students themselves? Is it due to the failure to give training in the proper subjects? Is it due to incompetence of the teachers? Is it perhaps due to the fact that teachers may be placing the emphasis in the wrong place, that is, to wrong methods in teaching?

As for this matter of the method of teaching, a fact which has not been sufficiently recognized in some of our educational institutions is that there is often very little of the so-called transfer of training. That is, a very thorough training in one subject does not make one better able to judge in another, except in so far as the two have points in common, and it is often necessary that these points be very similar. I was talking with an Englishman who had just received his degree of doctor of philosophy in botany from a leading English university. His sister was going to India as a missionary. I asked him what her subject of specialization was and he said, "French; it makes no difference what subject she takes so long as she gets an education." But one may wonder what relation a training in French literature and language would have to missionary work in India. It is true that educators in recent years have been emphasizing this lack of transfer of training, but it seems that in many departments of education, instead of teaching a few basic courses in such a manner as to favor transfer, they merely multiply courses. By so doing they hope to give specific information on methods of teaching each and every subject a teacher may wish to teach. To obtain a teacher's certificate in some states it seems more important that the prospective teacher has a separate course in the method of teaching each subject to be taught than that he has thorough knowledge in the subject he proposes to teach.

To me this trend is entirely in the wrong direction. No schooling can ever hope to give the answers to all the problems that might arise, whether they be problems in teaching or in any other field. I am of the opinion that there is much more transfer of the right sort than is commonly recognized. I have reference to one's attitude or method of approach to a problem in hand; that is, approach with an open mind, without prejudice; an attempt to ascertain all possible facts bearing on the matter; a search for opposing evidence; a critical weighing of the evidence; a recognition of what constitutes evidence; a readiness to recognize possible complexities and contradictory evidence; and perhaps that all the evidence is not yet at hand. Such training in critical method may be given in many different subjects and fields. But much of the schooling even in colleges and universities is not of such a nature as to give this training.

Mathematics and ancient languages are often cited as "excellent for training the mind, tending to make one think clearly and accurately." It is true that to a certain extent mathematics does require a critical and analytical attitude, but its relation to everyday problems is often remote. In one sense mathematics may be too rigid and straightforward, too much given to rules and formulae, too exact for education towards a more satisfactory life, because the problems of living are not so definite as problems in mathematics. Mathematics starts with clearly verifiable assumptions or arbitrarily makes its own rules, and is therefore likely to lead to over-confidence when one comes to deal with subjects in which the premises themselves are questionable or indefinite.

This tendency toward over-confidence is often apparent in those who have had a formal schooling and introduces a serious problem in the field of teaching and education. The old saying "A little learning is a dangerous thing" has a real basis in fact. If one

acquired a smattering of information, especially if the teacher presented it with great confidence and an air of authority, with no cautions or qualifications and with no indications as to degree of certainty or uncertainty, an individual is likely to act on it without real understanding; whereas one without this superficial training feels less confident and is likely to be more cautious in acting. When trained dogmatically to follow directions or apply rules without understanding the underlying principles, there is always a danger of misapplying them, as did the professor who thought he could cure appendicitis in his son by mental treatments.

It seems that much of the training in our grade schools and high schools and even in universities is of this authoritative or dogmatic type. The pupil is not trained to think for himself, for the major emphasis is placed on learning so-called facts. Day by day, more and more information is drilled into the minds of our students. They are led to accept some text or individual as authority and are not encouraged to form their own opinions or to use their own judgment. However, to accept blindly the opinions and statements of others, to accept authority, does not lead to understanding by the pupil. In fact, the teacher who teaches authoritatively teaches answers, and is not helping the student to learn for himself or to arrive at a real understanding. Such a teacher is likely himself to accept authority from others, and the matter he presents tends to become more and more unrelated to the truth and to lose real significance. Vitality leaves a subject when it is carried on by authority, no matter what the subject.

In the minds of many people "teaching" and the indoctrination of dogma are synonymous. At least this appears to be the interpretation of many legislators when they pass laws prohibiting the discussion by teachers of evolution or of cummunism; or of private citizens who write denunciatory letters to school superintendents or college presidents if they hear that some teacher has discussed socialism, communism or evolution. To them a teacher's only function is dogmatically to instill doctrines or "facts" into the minds of pupils; to tell them *what* to think, not *how* to think. I am not defending those teachers who are advocating the adoption of communism or any other "ism." These self-styled intelligentsia are often more dogmatic and more dangerous than the unthinking and dogmatic conservative. I say more dangerous because, with an abrupt adoption of untested schemes there is the likelihood of upsetting natural balances to which civilization has become gradually adjusted, and this sudden change may lead to entirely unsuspected and violent disturbances.

On the other hand, I am defending those teachers who are trying to encourage their pupils to think for themselves, to examine controversial topics in the hope that better understanding may lead to improvement. Although there may be marked disagreement concerning what constitutes improvement or just where changes should be made, few, if any, will maintain that no improvement of any sort is possible in political, scientific, social, religious or economic practices. It follows of necessity therefore, especially in a democracy, that the citizens should have training in evaluating the evidence that is offered in support of, or in opposition to, proposals of various sorts. If, however, teachers by choice or coercion merely pass on accepted information, education becomes static and there can be no progress; and yet many of our citizens, including also by far too many teachers, consider that the major function of an education consists in forcing the pupils to accumulate a mass of information, or in indoctrinating them with certain beliefs.

Advances in the various fields of the sciences during the past one hundred years or less have profoundly affected our physical well-being, and have also had a marked influence on thought not only in science but in the fields of philosophy, religion, economics and social relations. Because of a recognition of these great achievements in the fields of science, increasing attention has been given to the teaching of sciences in our schools. Usually, however, the main emphasis, and often the only emphasis in the teaching of science, is placed on the presentation of a formidable array of facts and information which the pupil is supposed to store in his memory. But is this memorization of facts the most important function of an education in science? If not, what should a student get from his course in science?

He certainly should get some idea as to the method and view-point of science. By method I do not mean the details of technique but the broader principles.

He should become acquainted with the methods of discovering facts, of obtaining evidence, and he should have experience in critically evaluating this evidence.

He should have some training in what constitutes evidence, and learn to distinguish between what is, on the one hand, mere assumption, dogma or opinion based on prejudice or on fragmentary evidence that is open to several alternative explanations, and, on the other hand, knowledge based on verifiable proof that is not open to alternative interpretations. To the man who bases his conclusions on dogma handed down from generation to generation, it may seem a new and revolutionary idea when he comes to realize that totally independent investigators can arrive at the same truth, even though they use different methods and start perhaps with different premises. The student should appreciate that something is true, not because some great individual said so, but the man discovered it because it is true. Neither apostolic succession, a controlled

school system, nor an inspired press is necessary to carry on truth. On the contrary, these are likely to prevent progress, not promote it.

The student in science should learn to evaluate evidence and draw his own conclusions, and not merely accept an answer given by a book or a teacher. I am afraid we teachers too often discourage independent thinking. We expect correct answers or answers in the same words as we ourselves have formulated them, and pay too little attention to the type of reasoning which leads to the answer. Often a minor slip leads to an unsatisfactory answer when the main line of reasoning is the student's own and is perfectly sound. In attempting to get the answer satisfactory to the teacher, the student is often forced to learn by rote. He may then present a suitable answer but have no clear idea as to the underlying principles. I knew of a high-school teacher of geometry who forced her students to use the same lettering as the text in proving a theorem. If the letters were changed she could not prove it herself. She had learned by authority, had memorized the formula, and was passing it on verbatim. She did not herself understand the proof.

The student in science should learn to use the principles he has been studying in solving problems for himself. He should be encouraged to make frequent applications of these principles to every-day happenings. This will favor the transfer of training and make the training of greater value.

The student of science should appreciate the willingness and keen desire of the true scientist to reconsider his former conclusions; to look for evidence opposing his conclusions, not only for that supporting them, so that all weaknesses may be discovered and removed from the foundation of the structure he is building; to change his opinion if necessary; or to reserve his conclusion and suspend final judgment if the evidence seems inadequate or contradictory.

Is it not true that commonly the chief emphasis, if not the only emphasis in teaching science especially in the elementary courses, is devoted to the imparting of information, presenting the results of scientific investigations? Even in many of the more advanced courses and in the texts at all levels, the method of presentation in the text, the questions asked in the text and by the teachers deal largely with information and not interpretation. When interpretation is called for, the student is often asked merely to recall or recite the interpretation given in the text or by the teacher. It may be useful to know the answers to questions concerning simple definitions, the dates of specific happenings, the conclusions of specified individuals, the descriptive characteristics of various structures or substances, lists of the names of things, etc. A teacher can ask and correct answers to such questions without great mental exertion. Perhaps that is why so many teachers have settled into their little ruts and are satisfied with that type of testing and teaching. Answers to a high proportion of such questions usually merely involve memorization and recall. Some of the facts asked for may be useful or necessary, but many are of no real significance. It would seem better to set problems that involve an understanding of the principles and their applications, problems that involve a critical evaluation of the evidence bearing upon interpretations. To solve these problems they must not merely recall a few facts but must understand them and be able to use them in their thinking.

Instead of placing the major emphasis upon memorization of facts and information, therefore, would not our science teaching be much more meaningful if we emphasized these other phases that I have just mentioned? Do not the same points apply also, though perhaps with differing degrees of emphasis, in all teaching, whether it be science, history, literature, economics or religion?

As I have just said, one really interested in the truth should be constantly on the lookout for possible flaws in his conclusions or in the supporting evidence, and should actively search for possible opposing evidence to make sure that he has not overlooked something. Unfortunately most humans in their desire to prove themselves correct are prone to shut their eyes to opposing evidence or belittle it when it is brought to their attention. This undesirable trait finds many illustrations in most fields of education, and its fallacies and dangers should be stressed in our teaching. One might wish that this weakness would not appear in the field of science, but of course all scientists are human and show the same trait in varying degrees. It was not long ago that I learned of the following episode. One individual who was engaged in teaching and research in a given field of science had found several questionable statements in a publication of a second individual engaged in the same type of work. The first wrote to the other offering to send him a list of the points which he questioned. He was astonished to learn, however, that the writer of the article was not interested even in finding out what evidence or what interpretations were being questioned. How a scientist could be so sure of himself that he isn't interested in learning what mistakes another investigator working in the same field may think he has made, or what alternative interpretations he may have to offer, is beyond my comprehension.

One might think that the increased teaching of science subjects in our schools, and a recognition of the marvelous advances resulting from the use of the scientific method would have valuable educational effects, giving training in more independent and critical thinking and in avoiding superficiality, inexactness and sensationalism. But in much of our teaching, per-

haps especially in our science subjects, the teacher or text supplies a systematic array of so-called "facts" which the pupil is supposed to store in his memory. We are trying to make walking encyclopedias, not intelligent beings. Where laboratories are used, the student is given a chance to familiarize himself more thoroughly with these facts, and to fix them more definitely in his mind. They also give experimental proof of the fact, which is certainly better than trusting entirely to teacher or text, but at the same time the experiment proves that the teacher and text are right. Usually the simpler and more dependable experiments are selected for the student to repeat. They are therefore almost certain to come out right. If not, the student becomes discouraged. The expected results, however, are usually obvious, so if the student does not get them he often "fakes" them. Have the experiments therefore been as valuable as we thought?

A university professor in a science subject not long ago told me that most of his laboratory experiments were "fool proof." He said, "They are bound to come out right even if the student is careless." His course is highly systematized; students are well satisfied; things behave as expected. A high-school science teacher told me recently that most of his demonstration experiments were "faked." I know of another university professor who doesn't hesitate to "fake" demonstrations at science meetings or to slip into the laboratory after the students have gone and add products to their experimental flasks to make the experiments come out "right." But does this give training in science? Will this training help the student when he meets everyday problems and must make his own decisions? Does not this lead to over-confidence, to a false confidence and eventually to disillusionment and bitterness? No wonder students after they leave school become discouraged when their theories do not work. No wonder children as well as older people, who have been trained by authority and dogma, in the home, in schools and in church, become so severely upset, or revolt against all their early training—the true and false alike—when some of the so-called facts, so dogmatically taught them, are eventually found to be false or based on no foundation of evidence. What training have they had in distinguishing the true from the false; in meeting and solving problems for themselves?

Personally I prefer to set up experiments that will not come out as the student expects, and I am occasionally pleased if they come out "wrong." If the student knows the answer, why do the experiment? If it comes out as he expected, what has he learned? It is true that he may remember the point more easily and if it is highly important—well and good. He may learn something also of the techniques of experimental science. If, on the other hand, the results are not those expected, he has something to explain. If his original idea was correct he may not learn much by proving it. If it was wrong he must modify his idea. More often the expectation was correct, but there was some slip in the manipulation, or some complicating factor that was overlooked. If he finds what it is, he has learned something. In attempting to square his results with his expectations he will learn something of science and scientific method. If the experiment is "fool proof" or the data are "faked" the student gains nothing and may lose much. Of course if too many experiments come out "wrong" a student is likely to get discouraged and blame the teacher, the equipment, his partner or the subject.

As our knowledge of facts and laws of science increases, I am afraid it is becoming increasingly true that so-called "science" is being taught more and more dogmatically. In physics, for example, or in chemistry or in biology, there are so many laws and facts that are known and well established that it requires most of the available time of a course to present a survey of these facts, and little or no time is left for considering seemingly contradictory evidence, that is, for training in scientific methods and attitudes. It is true that in these days the texts are being constantly revised so that the information is more nearly up to date than formerly. But many teachers using such texts complain because of the necessity of change. I know of one teacher in a field of science who prefers to use a text written in 1896 to those written more recently. It is easier of course to learn once for all time and not have to change. Perhaps such teachers would prefer to have their own subject as static as medicine was between the second and sixteenth centuries. Galen's writings on anatomy and medicine, which were written in the second century, were used as authoritative texts for one thousand four hundred years. Galen and his writings were used not as an example, not as a step toward a better understanding, but as a final authority; instead of a new beginning in medical advancement it was the end of advancement for 1,400 years. An inflexible text or creed or formulation of a principle or hypothesis, if fixed in its details so as not to allow for growth or change, although useful and an improvement at the time of its formulation is likely to interfere with progress. Vesalius about 1543 questioned some of the statements ascribed to Galen and began to investigate for himself. His teachings and his studies were considered sacrilegious, and he was persecuted for them and narrowly escaped death at the hands of the Inquisition. One of the students of Vesalius said that his teacher not only demonstrated new truths to him, but "so taught that the student could discover new truths for himself," could develop beyond what he was taught. *Is not that the test of sound teaching?*

When new interpretations or conclusions are pre-

sented in our revised texts or revised lectures are the old ones displaced and the new merely substituted for the old? Would it not be much better occasionally to present some of the old conclusions with the supporting evidence, then give the new evidence showing why it was necessary to change our conclusions? Some students, however, resent having to decide for themselves, perhaps because from childhood they have been told what to believe.

I was developing contradictory evidence of this sort one time when a student, who was carefully taking notes, slammed his notebook with disgust, saying, "You tell us one theory and then contradict it." Another time I was giving contradictory evidence and pointed out how I was not sure myself which interpretation was correct. A student asked, "Why bother about these things when you do not know yourself?" "Why bother about outworn, discarded theories?" "Give us the things you do know about and let the rest go." Give answers; give the "latest dope." I pointed out, of course, that some texts and some teachers do give one side only as the truth, others the opposite side, and I hoped that, by considering both sides they would have a better understanding of the real truth. I well remember the case of a student who dropped a course in plant taxonomy because the professor said he could not tell for certain to which of two species a given plant belonged. It was intermediate and had characteristics of both species. This student "refused to study under a professor who did not know his subject." I have also heard of another professor in the same field of botany, a member of an organization in which much of the teaching is by authority. This professor, when he found such intermediate plants that could not be definitely classified, destroyed the plants, remarking that "they were the product of the devil."

To present only clearly established information, leaving out all the uncertainties, gives the students an entirely wrong view-point. It is not training him in science nor does it give him understanding. A professor in a department of horticulture at a well-known college of agriculture was greatly liked by his students. He was clear-cut and definite in his teachings, telling the students just what to do. Several years later some of his students reported that this course, which as students they had thought the "best" in their university course, was really the "worst." The rules did not work and they had no training in meeting problems. I think it was Mark Twain who said that after a long life full of many experiences he had found that it wasn't the things that he did not know that gave him most trouble, but the things he knew that weren't so.

Another case that came to my attention was that of a girl who had taken courses in a department of home economics where the latest findings were presented, but with no training in evaluating the evidence. When she returned to the university two or three years after graduating, she attended a lecture in which the conclusions were in direct contradiction to those of her previous training. She had been taught facts and conclusions and had not been trained to draw conclusions from evidence. She was greatly disturbed and at a loss to decide what to do. With such methods of teaching information only, one would need to return to school every few years to keep up with the information. Perhaps our college degrees should be labelled "good for five years only." Why not teach in such a way that the student can carry on, as did Vesalius and some, but too few, of our teachers to-day? Not long ago there was an article by Christian Gauss[2] which bore the title, "Why Don't College Graduates Stay Educated?" In my opinion the answer is that we have not really been educating them. We have been merely giving them conclusions, answers to specific questions, and have not been training them in evaluating evidence, in the methods of solving problems for themselves, in methods of continuing education.

I was speaking along this line before a small group a few years ago when one of the professors (one whom I admire and one who is, I think, a stimulating teacher for advanced students) remarked that, contrary to his usual custom, he was that year using a text. The text made statements which he knew were wrong. He hated to let them go unchallenged, but since he was teaching from the text he said nothing. But of what value is the teacher if he merely drills his pupils on information, false and true alike, which is already available in the text? This same professor said, "Surely you do not bring contradictory evidence into an elementary course?" I replied, "Of course, I welcome an opportunity to bring controversial material into an elementary course, especially if it is of such a nature that the student can easily appreciate the evidence." Then the student can get some feeling for the method of science, a truer idea of the real state of things, a truer understanding. If one attempts to present controversial material in an elementary course or text it is likely to make the course too long or the text too bulky, or it may necessitate the omission of important material. But, on the other hand, I sometimes wonder if we don't try to make our courses too complete and thereby lose depth. By depth I do not refer to more detail. Detail is often unnecessary padding.

If time is limited, why not leave out of the lectures or discussions much of the well-known material? Of course the student must have some basic information, but that is available in the text or reference books and original articles. What he needs from his teacher is

[2] *Saturday Evening Post*, 208: 26, December 7, 1938.

not more information, but where to find it when he needs it; and still more how to evaluate it, and how to use it. In some elementary courses it may be better to use the historical approach and show how at one time the available evidence supported a given conclusion, but how new evidence has led to the necessity of change. Then by definite comparison one can show how some of our present-day conclusions may need revision in the light of new evidence not now apparent. With many of our students, most of them in fact in colleges of arts and sciences, an elementary course or two is all they will ever get in science, so if they do not get a truer picture in this elementary course, where will they get it?

That many college-trained people have little or no appreciation of scientific principles is indicated by the frequent appearance in current monthly and weekly magazines and newspapers of supposedly serious articles purporting to deal with science, and yet the writers demonstrate abysmal ignorance of some of the most elementary scientific principles. This is partly due, I think, to poor teaching in our elementary science courses, especially that in the biological sciences, and in part to the fact that only a small proportion of the students who receive the A.B. degree from colleges of arts and sciences have had more than one or two freshman courses in some science. From a preliminary study that I have been making, it appears that a large number of those students taking their major work in English, foreign languages, history, philosophy and such have had less than 6 per cent. of their college work in the sciences, including both biological and physical sciences, while about 50 per cent. of these students have had no biological science whatever. Yet it is from this group that a large proportion of secondary school teachers, writers and journalists probably come. These writers and teachers perhaps shudder at mistakes in spelling or grammar, and we all enjoy the "howlers" in student papers in history, geography and such; but too few have had adequate training in the sciences to recognize the frequency of the ludicrous mistakes in these fields as they appear in writings in supposedly reputable magazines and newspapers. There is little difference between many college graduates and those who have not gone beyond the eighth grade in so far as their mental attitudes or judgments in the fields of science are concerned. Recent articles like "Chemistry Wrecks the Farm," "The Chemist Conquers Agriculture," "Civilization Faces a Joke," and a host of similar supposedly serious articles, merely demonstrate the vast ignorance of the field of biology of many writers, journalists and editors. Newspaper editors would hardly dream of sending a reporter who had never seen a football game to write up such a game for his paper, yet they expect reporters who have had no training whatever in science to write on the work of scientists.

It seems to be assumed by many writers and editors that the only things that will interest the general public in science is the spectacular, the miraculous, the colossal or the seemingly impossible at last come true. Of course it is more difficult to make clear and interesting the more critical aspects of science and the scientific method, but opportunities for doing so are not utilized. That many people are interested in following the development of seemingly contradictory evidence and the unfolding of hidden clues is indicated by the wide-spread interest in detective stories. One wonders whether a similar interest in science might not be awakened.

The public is becoming so accustomed to startling and even revolutionary discoveries in the fields of science, to such sudden apparent shifts in conclusions, that there seems to be developing a rather dangerous attitude among certain people. It is true that some individuals are over-conservative, over-prone to decide once for all on a subject and never reopen it for new light. But others go to the opposite extreme, become so accustomed to change that they have no convictions, no basic theories of life; are so afraid of being considered behind the times that they go to the other extreme and blindly follow every new fad. This "open-mindedness," as they perhaps call it, might better be described as "empty-mindedness." Our public school system ought to combat this tendency and not foster it. The sophisticated and disillusioned youth who has no convictions and becomes skeptical of all things may have been forced into such an attitude because he has been dogmatically taught one contradiction after another, and has been given no solid foundation training for forming his own judgments. But here again, is it not the emphasis on the findings of scientific investigations, findings that have led to frequent changes in practices, which have given the appearance of insecurity? Is it not the failure to emphasize the method and attitude of science that is at fault? The emphasis has been put in the wrong place, on the seemingly miraculous result rather than on the rigorous discipline that led to the new discovery. Truth and the underlying methods of discovering truth do not change.

The public has become so accustomed to the seemingly miraculous accomplishments in the fields of science that instead of using the scientific method and examining evidence critically, building on a solid foundation, many people merely become more gullible and accept any claim, no matter how fantastic. You will all recall the recent excitement over the supposed invasion from Mars. The astonishing developments in the field of the radio seem on the surface highly miraculous and, to many who have no understanding of the under-

lying physical principles, it seems but a simple step to telepathy, and from that to communication with the spirits of the dead. I have heard college-trained people cite the radio as proof for spiritism. It may be amusing at times to let one's imagination run riot, and sometimes giving free rein to unchecked imagination, fanciful thinking or appeal to superstition may have no dangerous outcome. But, for example, if the faith healers could gain complete control over medical and sanitary procedures and practices, the unchecked plagues of smallpox, typhus, cholera, yellow fever, typhoid and such would decimate a large part of the population of the world, and what are now only isolated tragedies resulting from the failure of misguided and ignorant individuals to make use of proven remedies would become devastating conflagrations.

Is there not something wrong with our educational systems when in this so-called scientific age we find, among our high-school, college and university graduates, many who believe nothing definite and have no convictions, while many others will believe anything, no matter how fantastic? Is there not something wrong when so many join the ranks of the fundamentalists, fighting the teaching of truth about evolution and progress as it applies to biology? When so many others join the ranks of the "one hundred per-centers" opposing the recognition of truth in history, in economics, or in government? When many are so gullible as to be deceived by the most faulty and superficial reasoning? Has not the teaching of science failed when so many taking these high-school and university courses join the ranks of the faith healers fighting sanitation and health measures, degrading both religion and science? It is clear that some of the most elementary principles of science are disregarded by those graduates of our best universities who go to fortune tellers and astrologers for advice, or for spirit messages from the dead; who feel uncomfortable unless they knock on wood; are superstitious about so many things, about lucky or unlucky numbers, about black cats or walking under ladders; who rely on charms or "lucky" pieces of one sort or another, or who forward chain letters for fear of bad luck.

When we recognize these weaknesses of those who are the products of our institutions of higher learning, weaknesses typical of primitive peoples or those with but few educational opportunities, we must recognize that part of it must be due to weaknesses in our educational system and methods. Part, I am convinced, is due to the fact that large numbers of students, as well as teachers, have had little or no training in science, especially in those phases of the biological sciences that bear upon one's everyday thinking and behavior. Part, I feel, is certainly due to the emphasis on teaching *what* to think rather than *how* to think; to a tendency to teach by authority, by dogma, rather than for authority, for understanding.

One of the more telling points in an article by Dallas Lore Sharp on "Education for Authority"[3] was his free translation of the Biblical passages as follows: "The people were astonished for He taught them as one having authority and not as those who had gone to college." Is not too much of our teaching to-day like that of the scribes of old, too much like that of the followers of Galen, a mere passing on of information, with little or no training in understanding? Are we not failing in helping our students to gain a real understanding, to gain an attitude of mind which aids in solving problems, in the discovery, unfolding and appreciation of truth and a recognition of values? Are we building a foundation that will lead to further growth and to a more satisfactory living?

As I look at it, science is successfully taught only as its teachers can get their pupils to appreciate how advancement in knowledge is accomplished only gradually and by the critical examination and reexamination, the testing and retesting, of each step in a fabric of evidence; and how the truth is clarified only after the many possible weaknesses or alternative interpretations are critically examined and tested from all angles and by many workers. Training in science should make the individual more critical, not more credulous, should lead him out of superstition and not sink him deeper into the attitudes of the superstitious.

I have been contrasting methods of teaching science, that is, teaching by drilling the students to memorize the conclusions of others, a mere accumulation of information, as contrasted with training in evaluating evidence, in understanding and in solving problems for themselves. Is not a training for real understanding, for authority, immensely superior to teaching by authority or by dictation? Do not the principles apply to all ages from the first grades in school to old age? Do not the same principles apply also to each of us as individuals, not as teachers, but as students continuing our education? Are we as individuals meeting problems by attempting to understand them or are we accepting authority, either from our former or present teachers or from our own past conclusions which perhaps were based on incomplete evidence? Are we as individuals growing, or are we static? In all fields of education, whether it be art or music, literature, religion, sociology, history, government, economics or one of the sciences, we need education for appreciation not by dictation, for understanding not by indoctrination, for authority not by authority.

[3] *Atlantic Monthly*, 128: 13–21, 1921.