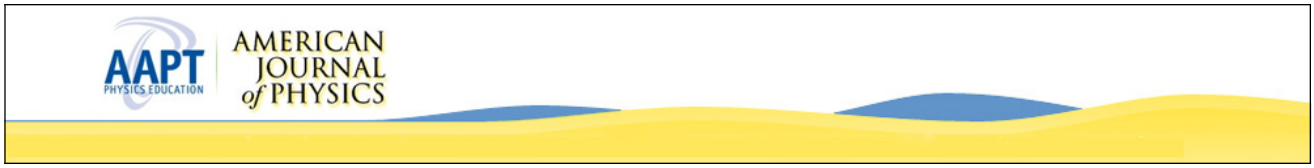

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F. K. Richtmyer

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The AMERICAN PHYSICS TEACHER

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Physics is Physics[1]

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PERHAPS I can best elucidate the rather cryptic title of this paper by quoting a remark of the late Professor G. W. Jones, Professor of Mathematics at Cornell University from 1877 to 1907 and one of the best teachers who ever occupied a professorial chair. It is told that an embryo teacher, taking one of Professor Jones' courses, once asked him: "What must one do to become a successful teacher of mathematics?"; to which Jones replied: "To become a successful teacher of mathematics one must acquire a thorough knowledge of mathematics."

I am sure that every member of Section Q, and probably many educationists, would agree with Professor Jones' statement, *as far as it goes.* I am equally sure that these same persons would agree at once with the converse statement that no person can become a successful teacher of any subject unless he possesses an adequate knowledge of that subject, even though that person may have had all of the courses in education given in one of the larger universities—79 of them at Cornell! May I point out, however, parenthetically, that the impression seems to be rather prevalent that there is another group of persons, composed mainly of certain other educationists and educational administrators, which takes issue with this second statement and which, to judge from the ever increasing number of semester-hours of education required of prospective public school teachers, holds the view that training in teaching methods is both *"necessary and sufficient"* to make competent teachers. With the views of this latter group I am not particularly concerned in this paper. Rather, I wish to discuss an obvious extension of Professor Jones' statement, an extension which he himself without doubt had in mind, as one would infer from his extraordinary success as a teacher.

That a knowledge of subject matter, however thorough that knowledge may be, is not of itself an *entirely* adequate preparation for teaching is at once recognized from the fact that there are many excellent scholars who are poor teachers. (I hasten to add, however, that many such scholars who are seeming failures as teachers of the more elementary branches of a subject are most inspiring teachers of the more advanced courses.) Something else than a knowledge of the subject is necessary. That something is, I believe, the acquisition of the *art* of teaching. And it is primarily to this last statement that I wish to direct my remarks.

Teaching, I say, is an art, and not a science. In a recent address before Science Service[2] Dr. Robert A. Millikan characterized a science as comprising first of all "a body of factual knowledge accepted as correct by all workers in the field." Surrounding this body of knowledge is a fringe, narrow or wide as the case may be, which represents the controversial part of the science. And outside of this fringe is the great unknown.

[1] A paper presented before Section Q (Education) of the American Association for the Advancement of Science at the Atlantic City Meeting, December 28, 1932.

[2] See The Scientific Monthly **35**, 203 (1932).

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Investigators are constantly exploring this controversial region; making hypotheses and theories; devising experiments to test those theories; and gradually enlarging the boundaries of accepted facts. Without a reasonable foundation of accepted fact, no subject can lay claim to the appellation "science."

If this definition of a science be accepted—and it seems to me very sound—then I believe that one must admit that in no sense can teaching be said to be a science. Probably every one would agree with this statement and perhaps it is therefore unnecessary to make it, except as a starting point for the discussion. But to make perfectly clear what I mean, let us consider an illustration.

If one were to select the ten best teachers of sophomore college physics in America and were to ask each one to write his statement of Ohm's law, one would find that the ten statements would be substantially identical except for differences in phraseology; for, Ohm's law forms part of the factual content of physics and is accepted as correct by all physicists. But if one were to ask those same teachers for a statement of the methods used by each in presenting Ohm's law to his classes, one would probably receive ten quite different answers. Each teacher uses his own methods of presentation, developed by him as best suited to his own personal traits and peculiarities, to the type of student whom he is at the moment teaching, and to the institution in which he is teaching. He has acquired his particular technique by the trial-and-error method, analyzing as objectively as he can his own reactions to the various methods which he has tried; studying the methods used by other successful teachers; and usually varying his procedure from class to class and from year to year so that he shall never become a mere machine. Though each of the ten men may be a highly successful teacher one searches in vain for any accepted body of factual knowledge upon which his success as a teacher is built. Nowhere do we find a basis for a scientific analysis of the methods which these men use. Rather, insofar as he is a teacher, each of the ten is an artist, with an artist's viewpoint toward, and an artist's pride in, his work.

The scientist pursues his work objectively. But is it characteristic of the artist that *his* work reflects his own personality. If he merely copies the work of another, he is no real artist. Certainly, there is no profession which has greater potentialities for reflecting personality than that of teaching. I repeat, then, that teaching is an art. If this statement be accepted as correct, we have taken an important step in any attempt to delineate the training which a teacher should have —in addition of course to his acquisition of subject matter—for in preparation for his *teaching* he should be trained in some respects as an artist is trained, and not as a scientist.

Now, the type of training given an artist differs widely from that given the scientist or the engineer. A student of civil engineering will study bridge design and construction; he will learn about moments of inertia of cross section, and about tensile strengths of materials; about cantilever construction and suspended arches; he will study the design and erection of great bridges—all this objectively. He will become familiar with the great body of knowledge accepted as basic in bridge engineering. And then he is prepared to undertake his professional work.

An artist on the contrary, say a violinist, acquires his training in quite a different way. He begins by actually playing the violin—as fathers and mothers are sometimes painfully aware! And as he plays he acquires skill, partly by virtue of increased experience, partly by the guiding comments and help of teachers who themselves are usually skilled violinists. He studies the works of great composers and the performances of great artists; not that he may imitate such performances, but that he may, by observing them, the better build a foundation for his own art.

It is important to note that there *is* a considerable body of scientific knowledge underlying music. For example, the frequency of vibration of a violin string of given length and mass per unit length is proportional to the square root of the tension. Therefore, in tuning the string a change of one percent in tension results in a change of two percent in pitch. If the violinist wishes to sound middle C on his G string he has to decrease its length exactly 25 percent. His open E string has a very strong fundamental and a prominent second overtone; the fundamental of the open G string is relatively weak while the third overtone is strong. The average violinist, however, is no more interested in these funda-

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mental scientific facts regarding the performance of his instrument than are the members of Section Q. He tunes his instrument and produces various tones and tone effects not according to formula, but "by ear." He would *perhaps* be regarded as a more cultured violinist if he *could* derive the formula for the frequency of a vibrating string; but his art as a violinist would not be improved by that accomplishment. In short, there is a very fundamental science underlying music, a science which it is very important to cultivate; but may I point out that the musician does not begin his education by studying that science.

Now, of course, I agree at once that one cannot carry the similarity between the training of an artist and the training of the teacher too far. There are very fundamental points of difference. For example, it is imperative, as I pointed out at the beginning, that the teacher shall first acquire a thorough knowledge of his subject—a knowledge which extends much beyond those parts of his subject which he is initially to teach. The musician faces no such preliminary requirement. The early efforts of the teacher cannot be as closely observed and directed as can those of the artist. The teacher, say, of science, must remember that though as a *teacher* he may be an artist, he is at the same time a *scientist.* He must approach the subject matter in his field *always* in the latter capacity. Without that approach he can never be a successful teacher. But he must approach the *presentation* of that subject matter to his students as an artist; without *that* approach he can scarcely become a successful teacher. The relation of teacher to students is, in general, much more intimate than that of the artist to his audience. And finally, I admit without argument, though with some reservations, that a part of the curricular subject matter generally referred to as "Education" is somewhat more closely connected with teaching than is the science underlying music, with music.

Nevertheless, there are certain aspects of the training of an artist which it is desirable to have in mind in our thinking on the subject of teacher training. For example, the music teacher periodically observes the playing of the embryo violinist, gives him frequent criticism and suggestion, and urges him constantly to study and to try to improve upon his own performance. Not so with the young teacher.

Probably the majority of college and university teachers get their first teaching experience by acting as teaching fellows or assistants during the period of graduate study. Since, on the one hand, the primary purpose of our graduate school is, *and always should be,* to offer to capable young men and women opportunities for advanced study and research, to the end that the spirit of productive scholarship shall continue to motivate our faculties of the future; and since, on the other hand, the student realizes that his graduate work is the *sine-qua-non* of that much-coveted doctorate, it is perhaps but natural that both student and professor should think of the former's teaching as merely a means of support during graduate study, which study is his main business. The result is that very frequently the young teacher, unlike the young artist, is left largely to his own resources so far as his teaching is concerned. He has begun his work with very little, if any, previous study of the problems of teaching. He seldom receive preliminary "coaching" from experienced teachers. The urge to analyze subjectively his own methods and performance as a teacher is usually lacking. As a teacher he "grows up like Topsy," not realizing, because no one has told him, that in preparation for his future career as a member of a college faculty, this opportunity to acquire teaching experience is second only to the opportunity to do graduate work. I believe that this situation is unfortunate, and should be remedied. But how?

There are those who urge that the graduate student should not be allowed to teach; that it is "hard on the undergraduate students" whom he teaches; that during graduate work he should, if he wishes to enter the teaching profession, prepare himself therefor by taking the various courses offered by the Department or School of Education. With these several views I partially disagree. Usually, the young teacher is selected and appointed on the basis of his potential teaching ability, as judged from his work as a student. *If the selection has been wisely made,* the young man will usually make up for any shortcomings in his classroom technique by a fresh and infectious enthusiasm for the subject taught. He is still close enough to his own difficulties as a

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student to be able to appreciate sympathetically those of the students under him. Somehow, he "muddles through" in spite of lack of guidance. The harm is not so much to his students. Rather it is to himself, for he has failed to make *best* use of the opportunity to acquire experience at a particularly important period in his development. Nevertheless, I have very frequently observed that those who develop into good teachers are good teachers almost from the start.

Further, I believe that the young teacher must acquire *his* art of teaching by actual teaching—not by studying in advance "how to teach," nor by play-teaching. Let me not be misunderstood. I regard the subject of education as a very important part of the curriculum, on a par with history, philosophy, chemistry or geology, and equally worthy of study and research. I would urge that it is just as important to offer students, whether they expect to become teachers or not, an opportunity to become acquainted with the history of education and with modern educational systems in this country and elsewhere, as it is to offer courses in the history of political institutions and in modern forms of government. Indeed I would even urge that, in parallel with his teaching, the graduate student who expects to become a teacher should take *suitable* courses in the principles and methods of education—if such courses be available!—not at all that he might find the subject matter of those courses directly applicable to his teaching in the same way that a course in bridge construction helps the bridge engineer—but rather that he might find in those courses yet one more inspiration to perfect his own art.

The responsibility, then, for training young teachers lies, I believe, with the subject-matter departments. It is the duty of the older, more experienced teachers in a department to impress the idea upon the beginner, by precept, example, and friendly counsel, that teaching is a serious business, requiring careful study; that his obligations to his students, present and future, require that he should make every effort to profit by the opportunity to acquire teaching experience under guidance; and that to this end he should strive to adopt teaching methods best suited to his own personal characteristics, to his students and to the subject matter taught. Indeed, the Committee on College and University Teaching of the American Association of University Professors recommends that, so far as may be possible, every college or university department should have on its staff at least one professor fitted by both aptitude and experience to advise with beginning teachers concerning their teaching problems. It is hardly necessary to point out that such advice cannot effectively be given by one officer for the university as a whole. For, the problems which the teacher of chemistry will encounter differ markedly from those encountered by the teacher of English; and further, it is almost imperative that the adviser should be more or less intimately acquainted with the young teacher's personal peculiarities and traits. In short, physics is physics; history is history; education is education. And there is not much to be gained by mixing them, so far as methods of teaching are concerned. Teaching, like charity, begins at home.

Granted, however, that the young teacher must develop his own art with such inspiration and help as he can get from his older colleagues and otherwise, should we not place before him a statement of what constitutes good teaching to serve as a standard of comparison for his guidance? I have seen many attempts to prepare such a statement, but I know of only one which is not open to criticism of the most serious kind: "Good teaching is the kind of teaching done by a good teacher."

I have in mind two teachers, neither now active. The one, a teacher of physics, was, as a teacher, an outstanding artist as I have used that term. He constantly studied his classroom and lecture technique. His methods and results would have justly merited the applause of the most critical educationist. He was recognized by both students and colleagues as a most successful and inspiring teacher.

The other was a teacher of engineering. To judge from the haphazard manner in which his teaching was done, he should have been a dismal failure as a teacher. But if one judges him, not by his classroom performance nor by grades received by his students in his courses, but by the only yardstick which is really trustworthy, namely, the extent to which his teaching influenced his students in their professional work

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after Commencement day, he must be regarded as one of the most successful teachers in America. He imparted not so much information as inspiration. His teaching simply reflected his own enthusiasm for the branch of engineering which he taught and in which he had made for himself an international reputation. I suspect that his teaching would have been colorless and ineffective, had he been required to use the more conventional classroom methods.

Dean Fernandus Payne in a report prepared for the Committee on College and University Teaching, above mentioned, describes the ideal teacher as follows: "If I were selecting a teacher I should look for a person of broad scholarly training, interest and culture; one who was interested in teaching; and one who could look upon the problems of the student with sympathy and understanding. This ideal teacher should have the energy and the enthusiasm which should accompany an inspiring and stimulating personality. I should look for a person who was logical in thought, thorough in preparation, and who was willing to work at the job. I should expect initiative, originality, adaptability, aggressiveness, and perhaps it would not be too much to expect a certain degree of refinement. Most certainly I should not avoid the man who was intensely interested in research." And Dean Payne adds: ". . . Such a prescription would be difficult to fill. . . . If you knew such a person there would be a wild scramble to get him. . . . In a generation, only a few such (ideal) individuals are found." The Mark Hopkins and the Agassizs are as rare as the Paganinis and the Kreislers.

It is frequently remarked that we American teachers teach far too much in comparison with our European colleagues; that it is better for the student if we expect him to take *some* initiative in his reading, studying and thinking. This criticism of the American method is, I believe, justified; but I do not think that the criticism applies to our *training* of college teachers. I do not think that we train them too much! Perhaps we overdo the matter of leaving them so much to their own devices. But even so, I believe that our present system is by no means a failure, though it is subject to improvement, we all admit. I believe that college and university teaching, by and large, is well done; that we have on our college faculties a large number of very capable, enthusiastic teachers. Only, we must be very careful to select the correct yardstick to measure success.

I believe that improvements may best be made by expecting the subject matter departments to take much greater responsibility for teacher training than they have in the past. I believe that we should make much more of an effort to seek out from among our students, both graduate and undergraduate, those who give promise of becoming good teachers, as well as those who give promise of becoming good scholars, and encourage the former to enter the teaching profession. Such selection can be made only by the members of the subject matter departments. Again I repeat: "Physics is physics." And if we leave the selection and training of physics teachers to the physicists, and place upon them the responsibility for doing a good job, we need never fear, I fancy, that subject-matter requirements will be neglected.

We may now complete Professor Jones' statement with which I began: "To become a successful teacher of mathematics one must acquire a thorough knowledge of mathematics, and then by constant practice, acquire the art of teaching it."

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