

CRITIQUE

of Teaching Objectives in Colleges

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IN agreeing to address this conference on the subject "Critique of Teaching Objectives—College" I had wondered whether this particular area was perhaps a little apart from our principal consideration, namely that of the improvement of high school science as a means of augmenting the production of future physicists. Now that I have listened to Fletcher Watson's report about the extremely small amount of college physics studied by the average high school teacher who is called on to teach physics, it looms as a very important aspect of our problem. Since it is evident that the general college physics courses provide essentially the only contact of the average high school physics teachers with this subject, it is of deepest importance to inquire as to whether the quality of such college physics courses is not to a large extent reflected in the manner in which high school physics is taught. Let me make two points clear at the very outset: first, I intend to be blunt and perhaps even brutal in my criticism of general college physics courses, and secondly, I wish to make it clear that I am excluding from such criticism those of my colleagues present at this conference who are engaged in teaching such courses. Now that I have cleared the atmosphere, I will drop all semblance of tact and state categorically that in my judgment the average elementary college physics course falls far short of even modest intellectual standards and fails utterly to satisfy present day requirements in physics education. This situation is deplorable, to say the least. I am amazed, not so much that high school physics leaves so much to be desired, but that it is as good as it is, when one considers the low quality of beginning college physics courses and the extraordinary difficulty which a high school teacher faces in keeping up even partially with the rapid advances in physics. The lack of professional competence of high school teachers of physics is undoubtedly due in no small measure to the mediocre standards of the average college physics course, and these in turn stem in no small degree from the un-

precedented rapid rate of growth of physics and its applications, as well as to the sharp increase in complexity and subtlety of modern physical principles.

Looking somewhat more closely at general college physics, and especially at its textbooks—and I hope I am not drawing too heavily on the material which Professor Michels will discuss later—one is struck forcibly by the unwillingness or inability of the college teacher to break with the traditional manner of teaching elementary physics and to modernize the spirit of his teaching at even a small fraction of the pace at which physics itself is growing. It is perfectly clear that college physics teachers, and especially those who devote themselves almost exclusively to the task of teaching elementary college physics, are influenced strongly by the physics they learned as students and find it unbearable to omit teaching the many applications of classical physics which have long ceased to be close to the stream of interest in present-day physics. In fact, much of what goes into a general college physics course under the name of physics has long since become an integral part of engineering science, has taken root in engineering education and research, and should properly be taught by engineers. In no way do I wish to create the impression that the esthetic satisfaction that one can derive from this material has in any way been diminished by the passage of time, but a choice must be made, and it seems just bullheaded to hang on to such material in this day and age. Of course, one always finds what to me is a most curious manner of trying to keep "up to date". Material is usually added to include many of the factual topics of modern physics, but this is more in the nature of appendices and afterthoughts than an integral part of the course. The last minute rush to try to make a student feel that he is being

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brought up to date is in many respects worse than omitting any reference to these topics. There is, however, a deeper aspect of the teaching of elementary college physics which leaves me perplexed and discouraged. Why is it that the teachers of these general physics courses pay lip-service to the unity of thought and a compact unified theoretical structure of physics, but then fail utterly to reveal in their teaching anything at all of the true spirit of science? Instead of attempting to show how advances in physical thought have enabled man to understand an enormous variety of natural experience in terms of a few fundamental physical principles, the teacher, having paid lip-service to this scientific spirit, turns his back on it and teaches physics in the traditional old compartmental series of topics: mechanics, heat, optics, electricity, etc. In many cases every attempt is made to wrap up each of these areas into neat little packages, tie them up with pretty ribbons, and proceed to the next package. I need hardly say more on this point.

One can get very sad or very angry at the teaching methods employed: The laws of physics are presented to the student by the teacher or the textbook, or both, as dogmatic truths. The student is to take them on faith and then proceeds to enter a period of learning how to apply these principles to applications of one sort or another to as quantitative a degree as his background and training will allow. This may be a fine way to teach theology, but it is a pretty sorry way of teaching science.

NOW that I have exposed to you my lack of respect for general college physics, let me turn briefly to a statement of what I think can be done to improve the situation. As now set up, the best that one can get, apart from mere accumulation of factual information, is a degree of quantitative analytic discipline. What is desperately needed is a strong admixture of an experimental approach in an attempt to develop a strong intuitive feeling for physics and good judgment about physical situations. It is necessary for a student to get some insight into the manner in which one tackles a situation where the answers are either totally unknown or but partially available, and not to have as his background only the ability to solve a number of oversimplified book problems which on the whole are related but loosely to real physical situations. I feel very strongly that the remedy for this unhealthy situation lies in an intensive approach to the teaching of physics from the laboratory standpoint, and I might say that we at MIT are making a major effort to improve the quality and effectiveness of our undergraduate laboratories. What is essential in good laboratory instruction is that a student meet a real intellectual challenge in terms of an experimental experience and not exclusively from words written in a book or emitted from the vocal cords of a teacher. If you think about the average laboratory experiment in elementary physics, I think you must conclude that the one who really learns any physics from such an experiment is the instructor who

has the task of getting the "bugs" out of the experiment and of reducing it to such a simple state that it checks approximately the pontifical statements of the lecturer or the textbook. Now such a laboratory experience, in which the laboratory is peripheral to the main body of the course, is degrading to both teacher and student alike, and certainly of minimal educational value. It is necessary to move the laboratory phase of physics instruction into the central core of the effort, to change the pattern of teaching from what I might call two-dimensional blackboard physics to three-dimensional experimental physics. It would be well if it were the goal of every elementary physics course to have the primary responsibility of teaching parts of the course laid directly in the lap of the laboratory so that the student meets the intellectual challenge for the first time as an experimental situation.

If this can be accomplished and physics taught as a coherent unit instead of a number of separate but loosely related topics, it should be possible to bring into being elementary courses which teach science in depth, driving home the importance and significance of the great principles of physics. This would leave the student with an open-ended foundation on which he can continue to build his professional competence in such a manner that his new knowledge will take the form of an evolution of thinking from his basic starting points rather than new closed areas to be added to a pile of older ones.

I would submit that we must have the courage to recognize openly the severe scientific limitations of the average teacher and to face the issue squarely that the primary need is that of his education. Of course, this education can and will occur if the teacher continues to grow professionally after he has ceased being a student. I am convinced that the only really good teachers of physics who will *remain* good teachers are those who stay alive in this growing science. The business of staying alive and reasonably up to date in physics I would place in the category of doing research; not in the restricted sense of uncovering knowledge heretofore unknown to mankind, but in the broader sense of solving problems and adding to the knowledge of the man who faces an area in which he personally lacks understanding, even though that understanding may be available to others working in the field. With this generalized definition of research, namely that a research problem must present a situation the answers to which are unknown *to the researcher*, it is plain that perhaps the most essential ingredient for the continuing improvement of college physics courses is to have the teacher do continuing research in this sense. With an increased vitality and stature of college physics courses, we could then look for a marked improvement in high school science teaching. It is part of the responsibility of the professional research physicist to help by advice and example in improving the quality of the average elementary physics course. It is to be hoped that the average college physics teacher would be receptive to such a cooperative effort.