be made on the skeleton plan. This is as shown in the photograph, but the plan is essentially as indicated in the diagram. To ensure easy sliding, rub a little paraffin on the sliding surfaces.

For enlargements it is necessary to clamp an extra length to the camera base to support the extension bellows.

Science teachers making lantern slides will find this or similar device invaluable in their work. After the picture or object is once placed on the easel, all further adjustments may be made from the rear of the camera

ON SCIENCE TEACHING. I.

By C. R. MANN,

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It is only within the last few years that the hitherto latent possibilities of science instruction have begun to become recognized. That they have been as yet wholly unrealized even in the work of the most inspired teachers is—alas—a too painful fact. For all teachers—certainly those of us who have pondered much on our opportunities and our achievements—must have come to perceive that the results of our labors, though partially satisfactory and oft-times encouraging, fail somehow to satisfy our inner consciousness or to make us think that we have advanced very far towards our ideals.

The teacher is assuredly not alone in this. For in these days of the restless development and the rapid expansion of our thought life and our ideals, it is natural that our attainment in all directions should find it difficult to keep pace with the advance. Yet the teacher of Natural Science seems to occupy a particularly difficult position, because, besides meeting the general conditions just mentioned, he has also to deal with a subject that is young and growing on the material side at an extraordinarily rapid rate. Hardly a month passes in which some new discovery is not announced or some new theory brought forward. How can he ever keep track of it all, let alone introducing it effectively into his instruction?

This is a question that every science teacher must face and answer for himself. No two teachers are ever placed in the same circumstances or ever have the same conditions to meet. There-

fore, no final answer can be given to it. It may, however, help us all in finding our own solutions if we can make our vague ideals concerning the actual and the possible functions of science instruction clearer and more definite—for no teaching can be forceful unless guided by definite aims and a clear understanding of the ideals toward which it is striving.

From the teacher's point of view perhaps the most important notion in physical science is that attaching to the word "exact." Physics, for example, is always spoken of as an "exact" science, and this term is popularly construed to apply to everything about it, its methods, its theories, its measurements, and its results. It is, however, of vital importance to the teacher to have a clear conception of the limits to the use of this word when applied to this subject. In how far are our observations exact? When are our methods exact, so that they lead to exact conclusions?

Everyone will agree that our observations are never exact, else why are we continually fussing about percentages of error? And yet nine-tenths of all scientists will agree that the law of the equilibrium of the lever, for example, is strictly exact. But if this result is obtained from approximate observations, how can it be more exact than the experiments on which it is based? Consider how the law is obtained. Suppose you are trying to lift a heavy stone by means of an iron crowbar. The pressure exerted by your hand strains the bar so that its particles are brought into a new series of relationships with one another, some being pushed closer together, some pulled farther apart. The prop or fulcrum on which the bar rests is dented and its particles deranged in an incomprehensible way. Similarly a vast series of changes is produced in the stone near the place where the crowbar touches it. In short, in this apparently simple experiment you are dealing with a vastly complex series of phenomena. To understand or solve the problem in its entirety, would be to fathom the mysteries of the Universe.

In the face of such a problem the scientist closes his eyes to the details of the actual phenomena, goes to the blackboard, makes a geometrical diagram, and says: "Let the straight line ABC represent the crowbar; B , the fulcrum; and the vectors AM and CN the two forces, etc." Then, with the assistance of the principle of

virtual displacements, the geometry of figures, and the work principle, he proves the "law" of the lever. The law thus derived is exact—at least as exact as are the principles or definitions or axioms that were used in its proof. Thus the law is exact not because of the accuracy of our observations of the corresponding phenomena, nor yet because of our hopeless inability to comprehend the objective reality, but simply because of our power of abstracting the actual into a geometrical diagram or an algebraic equation. Since this abstracting process is an act of the human mind, it appears that the accuracy of scientific laws depends in large measure on our own mental activity.

The development of the atomic theory of matter furnishes a capital example of the play of these human powers of abstraction. To Democritus, Lucretius, and Newton, the atom was a smooth, hard, indivisible, material thing. But Père Roscovich abstracted it into a "center of force," and the modern physicist has shown by mathematics that a vortex in a perfect, i. e., a physically inconceivable—fluid or plenum may have the properties that the atom is supposed to possess. This latter theory is a pure mathematical abstraction, since the medium in which the vortices twirl must have properties that render it physically inconceivable. Thus matter has become non-matter in motion.

A similar fate has befallen mass. Although scientists were unable to define it so long as they retained any notions of substance connected with it, yet the latest definition, namely, that mass is a coefficient in an algebraic equation, is certainly a masterpiece of mathematical abstraction.

All this reminds us of the Cheshire cat in *Alice's Adventures in Wonderland*, which "vanished quite slowly, beginning with the end of the tail, and ending with the grin, which remained some time after the rest of it had gone. "Well, I've often seen a cat without a grin," thought Alice; "but a grin without a cat. It's the most curious thing I ever saw in all my life."

A failure to realize the great role played by this abstracting process in science seems to be the source of a large number of our shortcomings as teachers. For example, if an instructor has once clearly grasped the fact that the so-called principles and laws of science derive their final accuracy from our powers of abstrac-

tion, can he confine the student's attention so assiduously as is often done to a percent, and percents, and half a percent of error? Far be it from us to decry the importance—nay, the vital necessity—of such considerations of accuracy in advanced research work. But do we not sometimes forget that the high school pupil is not a research specialist, and that he is as a rule not enamored of great accuracy? Do we not then develop rather his manual dexterity than his reason and his imagination?

In our eagerness to have well equipped and “thoroughly modern” laboratories, do we not often fail to make use of the vast fund of physical experience which everyone necessarily possesses simply because he has lived on this planet? Yet we often reject, in whole or in part, this fund of real experience—experience gained by having lived it so that it is part and parcel of our beings—and expect to develop a system that shall be comprehensive and exact on the basis of comparatively few rather clumsy stock experiments with half a hundred percentages of error thrown in for good measure.

But the real vitality of Physics is not in these external signs and symbols—this tinkling brass—but rather in the human part—the scientific imagination; and any student who leaves his physics class for the last time without ever having felt an inspiration to ponder over and to try to form images of the operations of the world forces amongst which he lives, has been filled with husks and empty forms and dwarfed in soul and mental growth.

Another of the serious errors—an error whose percentage is over 99—into which this idea of “exact” has lead us is that implied in the words “fixed and changeless.” For it is so easy to transfer these words from the operations of Nature to the descriptions of these operations as contained in scientific laws. Can we not keep clearly before us the fact that these laws are the production of man and that they are therefore at best incomplete and fallible? The Roman law was living and the soul of the Republic and of the Empire until it was “fixed” by Justinian. It was then what has been justly called the “Justinian Mummy,” and the Empire soon fell. The Christian religion was a burning, living inspiration to the early Church until it became “fixed” in a mass of dogma; and then, behold the Inquisition and the Reformation. It is none other-

wise with physical laws. When we "fix" them into a system of dogma, develop them into a logically perfect series, and then dole them out to growing, living, thirsty souls at the rate of so-and-so many pages a day, we are but exhibiting to them a veritable "physical mummy" and should not be surprised if the children turn from it chilled with indifference rather than warmed with enthusiasm.

Whenever we, either consciously or unconsciously, thrust upon a human being the idea that here at last we have something final and exact, we are lending our aid to the powers of death. For how does science grow? How are its new discoveries made? Does not every man in silence in his own soul construct his own world from the materials which he gathers in his lifetime? And what guides him in the building of it? Should it not be his own imagination—his own personal judgment acting in freedom? Should not his world then be an image of his personality? And are not all great things brought about by men of marked individuality—of powerful personality? But if in physics, or in anything else for that matter, we present to a growing mind a fixed system of thought—a mummy of any kind—will it help or hinder the free development of that greatest of human prizes, individuality? Will we be joining hands with the heroes of humanity in trying to establish yet more firmly the recognition of the inalienable right of every individual to absolute freedom of personal judgment; or shall we be secretly fostering intolerance? And intolerance has been powerful enough to cause the most powerful organizations to ruin themselves in their madness.

Clearly then the best teacher is he who keeps the path before the growing personality most open—who presents the facts, the theories, all the materials of instruction in such a way as to leave the individuality of the student free to act in silence in its own sweet way. It is the particular glory of science that this inner freedom is her heart and soul. A truly scientific judgment cannot be made unless the mind is wholly free. Let him who would tread on this inner freedom beware, "for the place whereon thou standest is holy ground."

The practical application of the principles just discussed must be worked out by each teacher in accordance with his own partic-

ular surroundings. Only the most general advice can be given to all. The most essential point is to ponder well the principles discussed and be sure that they are clear and well understood. Then bring before the students the materials of science, its facts and its theories; illustrate them carefully by experiments and the experiences of daily life; but be careful so to order and present them that each learner is free to build them into a world of his own. Above all, never let the young mind get the impression that what you give him is final, and never intrude upon his silence when he is engaged in the process of designing and constructing his world concepts. Advise and admonish him and call his attention to contradictory evidence when he seems to go astray, but never insist as a matter of authority that he is wrong. If you cannot make him conclude freely that you are right, leave him alone, for erroneous impressions are often of great value in learning science, and if you are right he will see it eventually.

The skill and the opportunity of the teacher, then, lies in the way in which he presents facts and theories; and his power and success often depends more on that which he leaves unsaid than on that which he says. The greatest error of most of us is, perhaps, that we say too much. Our redemption will be attained and our tremendous power fully realized only when we have learned to subdue ourselves and to let the truth possess the children from the things themselves. Our mission is simply to call their attention to the things of Nature and to the thought of men about those things; and when that is done, we should step aside and thus leave the growing personality of each and every one of them free to construct its individual world in a way that we comprehend as faintly as we do the original building of the objective world about us.

A SIMPLE STEP-UP AND STEP-DOWN APPARATUS.

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The above heading, though not a misnomer, covers only a part of the possibilities of a simple and inexpensive device. As many of the high schools are now equipped with the alternating current for lighting purposes, it occurred to me that this current might be