in many laboratory manuals, and it would seem that there had often been a failure to distinguish between directing a pupil's observations and actually making them for him.

The other weakness is perhaps more directly along the line of this discussion. It is that of setting pupils to work in the laboratory aimlessly or at least without sufficient guidance and then expecting them to observe all phenomena; discriminate between essentials and non-essentials; place all in proper relationship, and draw correct inferences from all these complicated phenomena. These things all seem very plain to the teacher; but to the pupil with his limited experience and training, they are as impossible as for a fifth grader to perfectly understand the change of seasons or the astronomical theory of the glacial epoch.

A PLEA FOR STUDENT LABORATORY WORK IN A FIRST COURSE IN PHYSICS.

THIRD PAPER.

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Near the end of the session last year the president of the college requested me to consider and report on the advisability of making a certain change in the method of work in physics. Desiring to base a report on as safe ground as possible, I submitted to the class, at the close of the final examination in physics, substantially (I have not the exact wording) the following questions:

1. On the basis of your own experience, compare the advantages and disadvantages of an experimental first course in physics with those of a textbook course.
2. Has your interest been mainly in passing on required work or in the subject matter? How would this have been affected if the course had been textbook work?

I asked for a frank, full and candid expression, stating that I wished it as an element for personal guidance in deciding a

question that had arisen regarding the work in physics. Response was voluntary and answers had no bearing on the examination just finished. All responded. The unanimity of opinion was surprising. To the first question only one response in a class of sixty-six favored the text. This paper is included below among those selected to represent the student view.

While I have no respect for that form of imbecility which panders to student opinion for the sake of a little cheap popularity, I strongly believe that students may have much to say on pedagogical matters, worthy of careful consideration by those responsible for the methods of the school. Surely the student side of the pedagogical problem is entitled to a hearing, and it has not yet been *over* heard. Hence I submit the papers below as written and with the consent of the writers.

It is but just to these young ladies to say that their opinions were formulated on the spot, without previous notice that they would be asked for or any intimation that they would ever appear in print and at the end of a difficult examination near the close of examination week. The purpose to print them did not then exist in my own mind. To those who know the girls the sincerity of these expressions, if it were not apparent in the context, is guaranteed by their names at the end. But for the benefit of those who do not know them it may be helpful to say that they had no knowledge of what the question being considered by me was, nor any intimation of what my personal opinion in the matter might be. Besides this, the questions submitted do not reveal or even suggest the question that was in my mind, but the answers give, indirectly, the evidence sought. The candor of these expressions is further attested by the fact that I asked at the same time that the defects of the course *as given* be pointed out and remedies suggested; and they were pointed out frankly and freely—some that I had not seen.

The average age of these girls was about 18 years, and they were Normal juniors in our four-years' course—one year from graduation. That some of the effects of the method of work would be greater in the case of these students than in the case of high school students, because of their greater maturity, is freely ad-

mitted; but the difference is one in degree, not in kind. It is the *kind* of results produced that is the chief concern in this series of papers.

"By a textbook course I would not have been acquainted first hand, but second or third hand, with the facts and principles of physics. I would not have been as deeply impressed, for it would have been only through memorizing or reading that my mind was impressed, and not through seeing and observing, which always makes things so clear to me. I believe and remember what I really see and perform. The laboratory course gave me a hand-to-hand acquaintance with physics. In dealing with it I felt that I was 'within the pale' of living reality and not on the borderland of a bookish friendship with physics. Again, if I had been given a 'textbook course,' how could I have been introduced to the method of scientific investigation? I am sure if I had studied a textbook I would not have gotten any habit of discrimination between fact and theory, for the fact and the theory would have been given me in unlabeled doses by the author of the textbook. Now, if I had studied a textbook and had no laboratory work, I do not see how I could draw or evaluate scientific conclusions. I have studied a textbook on physics before this and have found what I have said above to be true. My object and real interest in performing experiments was to see how the things would turn out, not simply to pass over so much required work. My interest in the subject matter would have been less had I taken a textbook course, for I am always more fully interested in what I myself do than I am in reading what some one else has done."

RHEA DALLAS.

"I think it would have been better to have had a textbook course. We are supposed to go to class without opening the book and there we perform the experiments or read over the text matter. The general facts and principles are not memorized, only read, and the girl is not really acquainted with them. Then, when examination comes, she has to cram all principles, laws, etc., in one night, and becomes confused from not having been required to learn while going over. I took a course in physics before coming to Winthrop and we had to recite the lesson. Experimental work was done before^{us}, and while I found the textbook hard, still I think I derived better results, because I had to learn each thing as I went along. I think the work is made as interesting as possible by experimental work, but I would have derived more benefit by use of the textbook."

CARRIE ONSLOW.

"I think I have gotten better results through this laboratory course in physics than I should through a textbook course. I have studied physics before in a graded school where we had lessons assigned to us from the book, studied these lessons and recited them in class. I found in studying

it again that I knew very little of the general laws, although I had had a good teacher.¹ For this reason I think the laboratory course has done me more good. Before, I studied the laws of physics, never questioning their truth and with little idea as to how they were derived. After the present course in the laboratory, in which we had to derive these laws, I do not look upon every law as a fixed statement of truth. And I have a better idea as to how scientific men have gotten these laws. It has supplemented our course in chemistry, while chemistry has helped us in this course. We have gotten a better idea of science in this course. I have enjoyed the course and have been interested in it, especially when we performed experiments ourselves, as we did, except toward the end."²

RACHEL BRAWLEY.

"It is an admitted fact that knowledge is got through the senses and laboratory work is the best means of securing this. Pupils may apparently learn more from the book, for they may cover more ground, so to speak, but certainly they will forget it more easily than those who have actually seen the things and thought about them in writing up their notes. I think writing the experiments is an important part of the work. To think out so as to be able to give a concise statement of facts will give more knowledge than reading textbook matter. I think this has been shown to me very clearly, for in my review for examination those things about which we had read and had done very few, if any, experiments were not half so easily remembered as those about which I had done experiments. My real interest was generally in the work, but in a few places I really took interest in it to be able to pass my examination. This was true only in the case when we were studying text matter (as we did near the end at some places in 'Light'), so I would say that my interest would certainly be greater in experimental work than in textbook work."

LEILA HEPBURN.

"The scientific method of investigation consists in having the investigator find out for herself—not to depend upon theory—to learn by doing. After the facts have been obtained, the scientific investigator draws her conclusions, inferences, etc., from them and discovers the theory through the facts. By a textbook course this could not have been realized, nor could the power of discrimination, of observation, and of drawing conclusions from given facts, have been cultivated. Then, too, without an appeal to the senses our course would have been a process of cramming for daily recitation and 'exams,' and after that, without the sense foundation, we would, most likely, have forgotten everything. Also, the laboratory course gave us an association with nature and this made our ideas much broader than they would have been otherwise. The textbook will soon be for-

¹This teacher is one of the very strongest men in the state—evidence that the best teacher must fail if his method is, *per se*, bad.

²The text was used toward the end of the year to enable us to "get over" the subject of "Light."

W. F. M.

W. F. M.

gotten, but the impressions I got by experimenting myself will last. While my interest in the study of physics has, no doubt, been greatly aided by the hope of passing, yet the work itself has been of the greater interest. If the work had been only textbook, without those experiments on electricity, magnetism, sound, and heat, it would have been tiresome to every one. I think the laboratory course far more interesting than the textbook course and if I ever teach physics I shall do my best to use the laboratory method."

MAE DELLE BARRE.

"One always remembers what she does and sees better than what she studies from a book. You can get the real meaning of laws, etc., if you work them out experimentally by concrete examples. Without the experiment you try to memorize laws without knowing what they really mean. You can memorize them, but certainly you will soon forget them. I have been very much interested in my work in physics this year. My interest has been in the experiments performed and the things, previously unknown, learned from them. I think a course from a textbook would have been much duller and also harder to understand."

CARRIE HUNTER.

"A more detailed knowledge of the subject might be gotten from the textbook, but much valuable training would be lost. The general facts and principles can be gotten from a textbook, but they will be better remembered from the experiments. The scientific method of investigation will be more clear to one if pursued in the laboratory. She also has opportunity to see for herself where theory comes from and where it often fails. She does not have to accept the textbook blindly. She can draw her own conclusions from what she has seen herself. Things become clearer and more real. I am certainly glad for other reasons that I took physics and took it by this method."

KITTIE KIRKPATRICK.

"When experiments are performed by the pupil they become more a part of himself and remain in his memory longer. Experimental work is a form of reaction and therefore facts learned in this way are clinched in mind. Laboratory work makes us more familiar with the material world and acquaints us better with the phenomena of nature, and thus makes our life more real and natural. Knowledge learned from textbooks gives the possessor a feeling of uncertainty and unreality. He feels like he is apart from nature and stands as if he were 'without the pale.' Again, laboratory work makes us more observant of things, makes us more accurate, makes us realize the inadequacy of mere verbal description in comparison with the actual doing of the work. It makes us more honest and precise, for we must do the thing definitely right or definitely wrong, thus making it impossible for us to hide our ignorance behind ambiguous words. Again, laboratory work holds our attention and interest and hence the

impressions gained are more lasting, for we work better when we do not work because we have to. In fact, laboratory work changes our entire conception of things and gives us a different intellectual attitude."

GRACE KIRKPATRICK.

"In textbook work we have a great tendency to get the words of the book, and by giving these to the teacher make him think we understand the lessons; and, in fact, we may think we understand it. In experimenting there is no 'fooling' yourself nor the teacher, for your work is before you and is right or wrong. If wrong, you do not lose as much as when you miss a question asked in class, for you find the cause of your error, which may be a great many times more valuable to you than if you got the correct result. By studying the textbook we get only the thoughts of others, while by doing the work ourselves we get original thought. I have found that in textbook study the work is pure memory, without association with concrete facts, of course with some abstract reasoning. While in our work this year there has been no memory without the concrete facts upon which the effects and reasons were based, all closely linked. I have not thought once about passing until I began studying a few weeks ago for examination. Then I worked to pass. But is not this fact an argument in favor of experiments? For the last few lessons have been textbook work. My work, such as it is, has been done from interest in the subject."

IDA SALLY.

"It is always hard to get laws and principles fixed in the mind when there is nothing concrete about them. But in dealing with concrete things the reasons for the laws and principles can be seen and then they are fixed in the mind, whereas words might be fixed there for a little while, but they soon drop into subconsciousness. I think I would have known more about geography if I had studied real things just as I have in physics, and it would not have required so much effort in trying to remember so many different things. Although physics is one of the hardest subjects I have, that is, as a textbook course, it has been made comparatively easy by the experimental work. At first I worked only to get through, but I became interested in the work and have enjoyed it. The longer I have worked at it the more I have liked it. I am sure if the course had been a textbook course I should have hated it, for of all things I hate to do it is to try to remember hard and dry laws when I can see no reason for them. But when I can reason them out they become interesting and I can keep them tight in my mind."

SUSIE PARKER.

"If we had used a textbook we would not have been acquainted with the general facts and principles of physics at *first hand*. At best we would have had to take the author's statement of them, and he may have been wrong, as we found when we made the experiment about the weight necessary to break a given substance. Our author said the breaking weight

varied inversely as the area of cross section, and we found by experiment that it varied directly. If we had made no experiment we would never perhaps have known he was wrong. We certainly did learn in our laboratory work how difficult it is for scientists to reach conclusions. There is so much room for error that I scarcely see how they ever reach any definite conclusions. If I learned nothing else, I learned not to be too positive that any conclusion we draw from a statement of facts or from observation is absolutely accurate. I don't think a textbook would ever have shown me this. Often I have crammed the words of a textbook without knowing the meaning of them or getting a single clear idea from them. I could not altogether get rid of the thought that I would have to pass on the required amount of work or take it over again; but in spite of this the experiments were interesting. I think textbook work would have been very uninteresting and hard to understand without actually seeing what took place. Many of the phenomena, especially in electricity, I had never seen, and I don't think a textbook would ever have given me a clear conception of them. I am afraid if we had used a textbook my interest would have been in passing."

EVA BEACH.

"I once took a textbook course in physical geography, and one may not credit this, but not until I began this course in physics did I ever once think of applying the knowledge of geography which I got four years ago to the world about me. Things which the textbook had cited did not attract my attention. I have enjoyed my course in physics a great deal and, as I told my mother Christmas, I think it has tended to make me look at things in a matter-of-fact way more than any other study I have ever had."

BESSIE ROGERS.

"In this work we found out things for ourselves and hence we were impressed with them more than we could have been by simply taking some one's sayings for the truth. In class we all studied the facts together and had things explained which we did not understand. (Many times we had the principal points emphasized and knew which ones to put most stress upon; also points we never would have seen ourselves.) I think this would be an ideal method, if we had time after going over experiments in class, to study the text and thus fix it on our minds. This experimental work is done in the study of botany and zoölogy to some extent, but we use the text to recite from. I have been greatly interested in my work—in finding out things I never knew before. It made me feel better every time I found out some fact experimentally that was hard to understand before seeing it myself. It was much more interesting to learn things experimentally and find out whether the author is correct in all he says than just to take everything for granted. You do not dread to go to such a class room as you do to many other lessons."

EDITH WILLIS.

"There are many things stated in the textbook that I never would have believed unless I had seen them. I might have said that the book said so, and maybe I should have thought so in an abstract way, but they would never have had the same meaning to me. Physics, as a whole, would have been unreal to me. I know this, for when I studied it once before all that I knew was that in a far-off region there was, for instance, such a thing as a lever. I did not know that nearly every kind of machine used *was one*, and that I saw one almost everywhere I looked. As to distinction between fact and theory, I thought everything that I read was fact. My interest might have been, at the first, due only to the fact that I had to do the work, but I am sure that I have never left the room feeling that I had not learned something. I have always enjoyed the work because I was always finding out something new. The course was far more interesting when we had experimental work than when we had the textbook work in the last part of the book. I was then usually glad when the period ended. But I do say that I have enjoyed physics more than any other subject in the junior work."

MAGGIE McFADDEN.

"One can always realize or take in anything more vividly and lastingly if seen with the eyes or got with some of the senses. An experimental course gives independence to the student and freedom from the servile following and swallowing of the textbook statements. In this way scientific facts and principles become familiar realities to the student—his acquaintance is first hand. The scientific method of investigation is followed in the experimental course and the student gets to know and like it. She gets the habit of sharp distinction between fact and theory inculcated by the handling and investigating of the concrete objects, and can discriminate between actual knowledge gained through the senses and theoretic knowledge arrived at by reasoning and implication. This method enables her to draw and evaluate any kind of scientific conclusions by her practice in deriving, testing and investigating. In general, this course prevents the learning by heart and learning mechanically so prevalent in textbook work and gives life and interest to science. When I began physics my interest was purely to get through, but in working I grew so interested that I would forget about marks, though marks are still of the highest importance in my mind. While studying or working in physics I did not think of passing, but was interested in the subject. There is no comparison between textbook and experimental work; hitherto all sciences have been distasteful to me and caused much memorizing and little understanding and philosophizing, and to my surprise I find that I am sorry to stop physics and that I have learned and can apply some scientific facts to things about me—something before unheard of in me."

SARAH E. REYNOLDS.