PRELIMINARY INTELLIGENCE TESTING IN THE DEPARTMENT OF PHYSICS, UNIVERSITY OF CHICAGO.¹

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If one is to regard a general course in physics as coming under the head of intelligence testing, the title of this paper will fairly well fit the subject matter. If, however, by intelligence testing we mean preliminary examination of a student with reference to his degree of fitness for his subject, our title, which was somewhat hastily chosen owing to the necessity of getting the program into print, applies to only a relatively small part of our remarks.

Preliminary intelligence testing in physics at the University of Chicago is merely one feature of the general reorganization which our college courses have been undergoing during the last five years under the immediate supervision of the writer. This reorganization has been necessary because of changing conditions in these strenuous years of flux. Two of the most important of these changing conditions have been the notable development of the applications of physics in industries during the last decade, recognition of which has been tremendously emphasized by the war; and, second, although not independent of the first, a very notable increase in the number of students. Ten years ago this department was running an average of twelve junior college sections, registering an enrollment of 250 students per year. During the present year we have estimated in eight junior college courses, 36 sections and a total of 820 students. Of these 36 sections, 28 are college courses. It is noteworthy that the decrease of registration in the University caused by the war the last two years has not been duplicated in physics and chemistry.

The distinction firmly insisted upon by the University of Chicago between college instruction and preparatory instruction in physics is identical with the distinction between the analytical method of treatment and the descriptive. We hold that no college course which is not analytical is a college course in the sense in which we use the term. We insist that in the vast majority of cases an analytical course cannot be carried successfully by a student who has not had descriptive courses in the subject matter beforehand. For this reason, claims for advanced standing brought from other institutions to us are frequently refused or at least granted only in part when it appears that these college courses have admitted students who have not had high school

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physics. We recognize perfectly well that the claim made by some college teachers that they cannot distinguish in their classes people who have had high school physics from those who have not, may be frequently justifiable. Nevertheless any college course which does not presuppose the descriptive work cannot be a strictly analytical course and cannot therefore be equivalent to the college courses of this University.

Our reorganized plan of college instruction appears to best advantage in those courses catalogued as Physics 3, 4, and 5, which constitute the year's sequence given in the fall, winter, and spring quarters, respectively. These courses meet nine hours a week and are expected to consume a total of fifteen hours a week of the average student's time, if time spent on preparation is included. Of the nine hours under definite instruction, one hour is devoted to a demonstration lecture attended by all sections together. Eight hours are devoted to classroom and laboratory exercises with practically an equal division of time between actual experimental work and informal classroom discussion.

The advantage of having a laboratory in which a class can draw up their chairs in front of the blackboard informally for common discussion of questions at any time has been pointed out with considerable emphasis before this association in times past. We consider it one of the vital features of successful teaching. With regard to the demonstration lecture, it has been adopted to a limited extent with a threefold purpose in mind.

First, if the senior men of the department are associated with elementary instruction at all, it is only in the demonstration work that this association can be made. Our elementary classes have an opportunity to become acquainted with Professor Michelson when he lectures on such subjects as the rigidity of the earth, interference of light, measurements of the velocity of light, or on problems in spectroscopy. They become acquainted with Professor Millikan in his lectures on the kinetic and the electron theory. In the course of a year they thus become acquainted with all members of the staff in connection with those phases of modern physics wherein these men have research reputations.

In the second place, there are a great many important applications of physics in modern civilization with respect to which the textbooks are never up-to-date. We have demonstration lectures on the fundamental mechanical principles of flight, on fluid motion, on the gyroscope, on the boomerang, on low temperature phenomena, on change of state, on Brownian motions, on

the periodic relations between the elements as brought out in the study of X-rays, on the measurements of "e," on the structure of atoms, on electrical oscillations, on harmonic analysis of sound, on water waves, on applications of spectra to the problems of the stellar universe, as well as to the structure of the atom, on X-ray spectroscopy, on interference and diffraction.

The lectures on these subjects are real demonstration lectures in which upwards of three hundred different experiments are performed before the class. Very careful study has been made to enable the presentation of this material divorced from mathematical complexity. Even such phenomena as the gyroscope and the boomerang have been successfully attacked with no more mathematical machinery than that involved in a vector addition diagram. While some of the apparatus involved is elaborate and costly, by far the major portion of it is simple and obvious.

In the third place, while students are expected to understand and are examined on the material presented in demonstration lectures, these lectures are nevertheless conducted with a view toward general relaxation and relief from the strenuous grind of laboratory routine measurements and computations, and if students' comments are to be taken as any indication, the demonstration hour each week is the most enjoyable of the course.

For the benefit of teachers and advanced students, this demonstration material has been collected into a special single course offered as Physics 7 in the University College during the year and given usually under the same notation as a teachers' course in the summer quarter. When so organized, much more emphasis is laid upon the analytical aspect of the work and the course thus carries senior college or graduate credit.

In the laboratory continual effort is also being made toward modernization of the classical material. The efficiency of the 4-cylinder, 4-cycle gas engine is regarded as a more desirable experiment than one on the efficiency of the water motor. The graphical analysis of the tensions and compressions in a simple bridge of which the model is before the class is thought to be of more value than routine problems assigned on the basis of geometrical figures representing tensions.

We regard it as highly important that the same man be in charge of both laboratory and recitation work, but in view of the large number of sections involved in these courses in each one of which the instructor has full responsibility over classroom and laboratory work, careful coordination must be made. It is im-

portant on the other hand that independence in the presentation and entire freedom in teaching be in no way sacrificed. Consequently the general physics course can be accurately described as being given by a committee composed of all of the instructors. The instructors and their assistants meet at frequent intervals to discuss the technique of experiments, problems, text and examination questions, and individual student cases. The final examination is worked out for the entire course by this committee of the whole. The classes are informed of the method used, which promptly establishes a cordial relation between the instructor and his individual group. Student and teacher are co-operating with the ultimate aim of passing the course, the standard of which is fixed on an entirely impersonal basis; even the marking system is not arbitrary but grades are referred to the average of the classes, a procedure perfectly legitimate when numbers of students mounting into the hundreds are involved.

Finally, great care is used in admission and early examination of students in these courses with a view toward discovering their individual lack, either of preparation or of ability and it is here that we come to the subject announced in our title—the question of preliminary intelligence testing.

At the first meeting of all University classes in physics the following data are secured upon a form card from every registrant in each class: Name; age; classification in University, that is to say, A. B., S. B., Ph. B., J. D., M. D., etc.; year in University; high school physics taken, when, where, and with what textbook; previous mathematics courses in high school, in college; previous science courses in high school, in college; other courses taken simultaneously with the present course in physics; why is the student now registered for this particular course in physics. These cards, upon which is entered in due course of time the student's academic history in physics, go into a permanent departmental file and are available for future reference.

At this first session an efficiency test is also given. Questions are dictated and answers are to be written down at once, although sufficient time is allowed on each question to enable the student to put it down on a pad of paper if he so desires. Students are assured, however, that the questions are of such nature that it should not be necessary for them to have to "stop and think" for any extended period. These questions cover high school physics and some arithmetic and algebra. For example:¹

¹Some of these questions are taken from that excellent little book, "An Introduction To Laboratory Physics."—*Tuttle*,

How much current does a 50-watt lamp consume on a 100-volt circuit?

What is Boyle's law?

How many degrees below zero is absolute zero, and why this number?

What is the difference between yellow and green light?

$(m+x)(m-x) = ?$

Reciprocal of $2/7 = ?$

Solve: $3 : 12 :: 16 : x$

Reduce: $\begin{cases} .395 \\ .005 \end{cases}$ to percentage

Simplify: $a^5 \times a^3$, $a^3 \times 5$, a^{4+2}

If pv is the constant, how is p affected by doubling v ?

Equation $y = ax - b$; solve for x . What is y equal to when $x = 0$?

The results of these questions are entered on the students' record cards and carefully studied before the second class meeting. Students who show averages below 50 per cent have their records carefully scrutinized and are then interviewed. Many of these are clearly out of place and change their registration at once without any further pressure being brought to bear. Others make protest and are always allowed to act in accordance with their own wishes, particularly when they feel that the result of the test is not an accurate indication of their potential capacity for the work.

Some statistics of this year's classes may be not without interest: of 171 registrants, 40 were below 50 per cent and were interviewed; 22 cordially agreed that they were not prepared for college physics and dropped out at once with a loss of but one hour's time in entering another class. Many of these requested advice as to what they should take and acted directly in accordance with it, some going back into preparatory physics, others taking elementary courses in mathematics, some going into chemistry. The remaining 18 students were all warned as to the importance of carefully scrutinizing their reactions in the first few weeks and advised to make special effort. Of these 18, 9 stayed by the work and are now ultimately making good; 9 others dropped within four weeks because of obvious failure to continue with a passing grade. In the last four weeks several other students have dropped, but these cases have almost without exception been due to conditions arising late in the quarter, mostly because of illness, a condition which has interfered with the rest of their University work as well as with their physics.

We find without exception that some of the greatest deficiencies of our students are connected with ideas of mass and weight, and with the definitions of velocity work and power, all of which they should have learned in high school. After three weeks in their college course this fall in which there had been ample review of these notions, the following questions were given:

What is the difference between mass and weight?

Define velocity, acceleration, work, power. Answers were graded:

- A. Unquestionably correct.
- B. Nothing incorrect, but incomplete.
- C. Partly right and partly wrong.
- D. Entirely wrong.

Out of 425 answers 180 were A or 42 per cent; 112 were B or 26 per cent; 83 were C or 20 per cent; 50 were D or 12 per cent. With respect to the definition of velocity, however, there were only 18 out of 85, or 21 per cent who included the idea of direction in their definition, and these came almost entirely in one section taught by a British trained man who had laid especial stress on the matter. Apparently our students came from high school courses, this year at any rate, entirely innocent of any vector notions or of any distinction between velocity and speed.

It is far too early to attempt any analysis of the situation with respect to our incoming students with reference to the schools from which they come, but we feel that we will soon be in possession of valuable data in this direction. This year we have, out of a total of 171 registrants, 90 from out-of-town high schools and 81 from the high schools of Chicago or its suburbs. Of the out-of-town students, 22 per cent have been doing unsatisfactory work, C— or below, not necessarily failing in all cases, however, and of the city students, 28 per cent fall in the same category. It is too soon, however, to generalize from these results. It is obvious that our records can be analyzed with respect to any individual school as soon as we have a little more time to gather statistical material. We urgently desire to get the cooperation of the high school people, particularly around Chicago, in studying this data, which will, of course, be freely taken up with the instructional staff of any particular school in so far as it relates to that school. It has invariably happened during the writer's experience of the last four years as departmental examiner that cooperation between the University and a high school based upon a mutual discussion of the teaching problems involved in both institutions has resulted in recommendations through the Examiner's Office, the adoption of which has rendered material improvement in the working conditions in the high school and in the equipment of the students which were there being prepared.

In closing, it is needless to emphasize that we do not expect by merely gathering data to solve the great problems of teaching. Anything which pretends to do so can be safely set down as a nostrum and consigned to oblivion. The problems of teaching will differ from generation to generation as human nature shows individual variation.