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THE COLLEGE STUDENT'S KNOWLEDGE OF HIGH SCHOOL PHYSICS

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On the question of the value of high school work in physics to the student entering a college class in the subject, there is no unanimity of opinion amongst college physics teachers. There are a few who think that the college should offer two courses—one for those students who have had a year of physics in the high school, and another and more elementary course for those who have not studied the subject. At the other extreme are those teachers who maintain that they prefer students who have not had any physics work in the high school and who, therefore, have “nothing to unlearn.” Between these extremes are those teachers who say that they do not care whether or not their students have had high school physics, that they place those who have had and those who have not had the work in the same class and that the two groups make practically the same grades in their college work.

Believing that opinions should be founded on facts rather than on impressions, the writer concluded to give his beginning students an examination to discover how much of their high school physics had been carried over into the University.

It was carefully explained to the class that the examination was a pedagogical study and that the grade made by a student would not be considered in determining the grade on his term of college work. The students were urged to co-operate with the teacher by trying to answer every question, whether certain or doubtful as to the answer, and whether they had taken or had not taken physics in their high school course. I am sure that there were very few cases in which the student did not do his best.

At the first session of the class, the fall term of 1916, each

student was handed a three page list of questions. The first page was as follows:

TABLE I. Date

College	
Name	
From what high school did you graduate?	
Date?	
Did you study physics in the high school?	
How long?	
Have you studied physics in any college or normal?	
Where?	How long?
What subjects?	
Of what college class are you now a member?	
What is your major study?	
Have you ever taught physics?	How long?
Where?	

Please answer quickly and briefly the ten questions on the accompanying lists. If you are not sure of the correctness of your answers, give them anyway.

On the second and third pages was a list of ten physics questions with sufficient space after each question for the student to write his answer. The questions were as follows:

TABLE II.

1. What is the resulting volume if 1,000 cubic cm. of gas at a barometric pressure of 1 atmosphere (76 cm. of mercury) be subjected to an additional pressure of 4 cm. of mercury?
2. Taking the coefficient of expansion of steel at .000011, find the total length of an iron bridge at 20° C. if its length at 0° C. is 100 feet.
3. What is meant by the statement that the specific heat of iron is 0.113?
4. A 2 candle power lamp is placed 1.5 meters from a screen. Where must an 8 candle power lamp be placed to produce the same illumination on the screen?
5. What is the apparent color of a pure red (monochromatic) object when viewed in pure (monochromatic) blue light?
6. What is meant by the statement that a lens has a focal length of eight inches?
7. What causes the refraction of a beam of light when it passes from one medium into another?
8. What current will flow when the terminals of a 1 volt cell having an internal resistance of 2 ohms are connected through a resistance of 5 ohms?
9. What current is required to operate a 40 watt 110 volt incandescent lamp?
10. What principle is illustrated when a dynamo is generating a current? In other words, how does the dynamo generate an electro-motive-force?

In preparing the above questions, an effort was made to make the list equally fair to physics teachers using widely different methods. Some high schools have practically no equipment or an equipment that is useless because of unintelligent selection. The teacher in such a school is likely to be burdened with classes in several subjects and thus be forced to make his physics work wholly text book work. He may stress theory, or definitions, or problems.

Another teacher who has more time and more equipment emphasizes laboratory practice. Still another believes that physics must be practical and that nothing is practical that does not have to do with watts, or horsepower, or some other term used in commerce or industry.

The writer graded the 110 papers returned on this examination, made a detailed study of the results, and presented the data and conclusions to the college physics teachers of Indiana at the annual meeting of the club, May, 1917. The club voted that the writer extend the study to include the beginning physics classes of the several Indiana Colleges represented at the meeting. The writer expected to make the study the following fall, but owing to war excitement and to the disturbed school conditions immediately following the war, the study was postponed till the fall of 1920 when the examination was given in seven Indiana colleges besides Indiana University. The fall of 1921 the examination was repeated in Indiana University and in two colleges not on the 1920 list. The writer in every case sent to the college giving the examination a supply of question sheets identical with those used in the 1916 examination. The examination was given at the opening of the fall term and the papers were returned to the writer for grading. Thus all the students taking the examination, 1,058 in number, wrote on the same questions and all the papers were graded by the same person.

The teachers and institutions co-operating with the writer and Indiana University in this study were: Professor Ryland Ratliff of the Central Normal College (C. N. C.), Professor J. P. Naylor of DePauw University (D. P.), Professor L. E. McCarty of Earlham College (Earl.), Professor J. E. Smith of Franklin College (Frank.), Professor E. S. Ferry of Purdue University (Pur.), Professor E. S. Johonnott of Rose Polytechnic Institute (Rose), Professor Robert G. Gillum of the Indiana State Normal School (St. N.), Professor B. A. Howlett of Valparaiso University (Val.) and Professor E. K. Chapman of Wabash College (Wab.).

Table III summarizes the results of the several examinations. Column 1 suggests the nature of the questions, columns 2 to 11, inclusive, give for each question the average grades (on the basis of 10 per cent per question for the ten questions) of all the students of the ten colleges participating in the study. Column 12 gives the weighted average of all these grades—each institution grade being weighted in proportion to the number of students making that grade.

TABLE III
AVERAGE GRADES (%) OF ALL WHO HAD STUDIED HIGH SCHOOL PHYSICS.

1 Question	2 C.N.C.	3 De. P.	4 Earl.	5 Frank.	6 Ind.	7 Pur.	8 Rose	9 St. N.	10 Val.	11 Wab.	12 W. Av.
1 100 c. e. gas at 76 Vol. at 80?	2.5	1.7	3.1	3.3	3.3	2.5	3.4	2.2	3.0	4.0	2.7
2 Length 100 ft. bridge when t. rises 20°?	2.5	4.3	2.1	3.2	3.6	3.1	5.2	7.2	5.0	3.7	3.5
3 Specific heat?	0.0	1.5	1.5	1.5	1.7	1.0	2.8	4.6	3.2	1.9	1.4
4 2 c. p. lamp at 1.5 m. Where 8 c. p.?	0.0	0.5	0.5	0.3	0.7	1.1	0.2	2.1	4.0	1.1	1.0
5 Color of red object in blue light?	2.5	0.5	0.5	0.9	1.9	0.8	1.6	2.2	2.0	0.0	1.5
6 Focal length of lens?	0.0	0.5	0.4	0.3	1.3	0.5	1.6	0.0	1.0	0.6	0.9
7 Cause of refraction?	1.2	2.4	2.1	1.6	2.2	2.2	1.3	3.4	1.9	2.2	2.7
8 1 volt thru 5 ohms. What the current?	0.0	0.5	2.1	1.5	1.5	1.2	2.7	0.1	2.0	0.5	2.5
9 40 watt 110 v. lamp. What the current?	0.0	0.5	0.5	1.1	1.4	1.2	2.0	0.0	1.0	0.4	1.2
10 Dynamo principle?	0.0	1.7	2.5	5.0	2.2	3.0	2.4	0.1	1.8	4.0	2.3
Total Grade	8.7	14.1	15.3	18.7	19.8	16.6	23.2	21.9	24.9	18.4	19.7

The last line of Table III gives the total grade on all ten questions, *19.7% being the weighted average of the grades made by 851 students who had studied physics one year in the high school.*

The limits of this paper preclude a detailed discussion of all the points suggested by a study of Table III, and of the other tables in which the grades have been analyzed from other viewpoints. The reader must do most of the theorizing. The writer will confine himself to a few points.

The differences shown between the grades of the students of the several colleges are easily explained. The relatively high or relatively low average of some of the schools having small classes is accidental, a particularly good or a particularly poor paper changing the average grade by several points. The Purdue average was brought down several points by fifty agricultural students whose average grade was about half of that made by students in other fields.

The claim that physics can be "put across" by dealing with "practical" things is not substantiated by this study. The majority of teachers certainly agree that question nine is a practical question, and that question seven is more theoretical. Yet one student of every four answered seven correctly, and but one of every eight could answer the ninth. And what is even more to the point, the students who were from high schools in which the teachers claimed to emphasize practical physics did not average better grades on this question than were made by students of other schools.

Poor grades can not be attributed to lack of laboratory equipment. Take, for instance, question six. The point can be experimentally demonstrated with a spectacle lens. Yet the grade made on this question was the lowest of all, only one student in eleven answering the question correctly. Questions four and five can be experimentally answered with very little equipment, while one, two and ten require considerable equipment. Yet the average grades on the latter questions were the higher, even in the case of those schools known to have little or no apparatus.

Whatever else we may see in Table III, the one outstanding fact is that the pick of high school physics classes (as those students who go to college are supposed to be) can answer only one question in five on such a list of physics questions as was

used in this examination. I shall discuss this point later. Just now I wish to answer some of the points raised by a group of high school teachers to whom I showed the data given in Table III, and who were very much surprised at the poor showing made by their students. In explanation some thought that the students had simply forgotten their high school physics in the interval between the completion of their high school course and the examination. Others held that the low average grade was due to the very inferior work done in a few high schools, chiefly "small high schools with few teachers and limited equipment."

TABLE IV.

Time between high school graduation and this examination	Number Examined	Average Grade
Less than one year.....	67	20.1%
More than one and less than two years.....	330	15.8%
More than two years.....	334	14.7%

Table IV shows that the actual amount of physics forgotten by the students could not have been very great. From 20.1% to 14.7% in two years and more is a large relative but a very small actual loss.

TABLE V.

Where Physics work was done	Number	Grade
One year in large high school.....	304	21.0%
One year in small high school.....	547	17.1%
High School Graduates, no physics.....	120	5.7%

Table V shows that the small high school is not responsible for the low average grade made on this examination. In the table the writer has included under the heading "large high schools" all high schools in cities having a population of fifteen thousand or more. The "small high schools" include all others—both commissioned and non-commissioned. The table shows a difference of less than 4% in favor of the large high school. The grades made by those coming from most of the small high schools were fully as good as were made by students from the large high schools. The facts are that the knowledge of physics acquired in a high school class can not be gauged by the size of the school or the excellence of its material equipment. A striking proof of this assertion is the fact that in a certain large city having two high schools with practically equal enrollments and having supposedly equal facilities, the average grade of the students from one of the schools was 34.5%, from the other school 13.3%. Of the 851 high school graduates who had had a year of high school physics, there was but one student who made 100% on the examination, and he was from one of the smallest high schools in the state.

People in Indiana have learned that because a basket ball team hails from some unheard of school—a school so small that every male student must play in order to secure a team of five, is no reason to suppose it can not or will not win over teams carefully groomed by high salaried coaches and chosen from hundreds or even thousands of aspiring players. The team from the cross road school house may “put it on the map.” If losing teams could take their cities off the map, the names of a number of Indiana cities would not appear. If a map were made on which the size of the type used in printing the name of a town was determined by the quality of the physics work done in its high school and not by its population, people would have trouble in recognizing their state. A number of towns, some with popular and supposedly efficient physics teachers, would not be on the map at all. Of sixty-five students coming into the writer's class from a certain high school in Indiana, more than eighty per cent failed to pass their first term's work. Of eighty students entering from another school, eighty-five per cent passed. Neither school appeared to have the advantage of the other in material equipment. The difference was in the teacher and in the spirit of the school in which he worked.

TABLE VI.

Preparation in Physics	Number	Av. Grd.
One year of high school physics.....	851	19.7%
One term or more, normal school physics.....	40	23.9%
One term or more, college physics.....	27	29.8%
No previous work in physics.....	140	4.6%
Men.....	978	19.7%
Women.....	80	11.0%
Men and Women.....	1058	18.1%

Table VI needs little comment. There was but a small difference between the grades of the students who had had a year of physics in the high school and those who had taken a term or more in a normal school or college. This is partly due to the fact that about half the latter had taken but one term in a normal school or college, and to the fact that those who had taken a year's work were inferior students or they would not have been taking beginning college physics a second time. However, the student may not have had any *real* college physics. *A course based on a text book of high school grade is not college physics, even though the work be done within college walls.*

Table VI shows that as a class high school boys are probably more interested in physics than are the girls. However, the

difference is not as great as the table indicates, for the per cent of girls who had not studied physics in the high school was greater than in the case of the boys. Eliminating from each group those who had not taken high school physics, the difference in the grades was small.

TABLE VII.

Major Study in College	Number	Grade
Engineering.....	262	15.8%
Mathematics.....	86	16.0%
Physics and Chemistry.....	96	24.6%
Agriculture.....	50	9.3%
All others.....	387	12.0%

Table VII shows that the "major" study of the college student is reflected in the grades made on his physics work in the high school. It is doubtless a question of where the student's interest lies, and not as to his ability. The low grade of the students of agriculture does not mean a low average of intelligence. It is due in large measure to the regrettable fact that students of agriculture, as a group, do not see where physics is practical for them.

Another point that was raised by the high school teachers commenting on the results of the examination, a point which should be taken into consideration by the reader, had to do with the rigidity of the grading. A very rigid grading would have reduced the average grade of the class to less than 10%, a very loose grading might have raised it to 30%.

The writer was not at all exacting in his grading on these examinations. He gave the student a zero grade when he said that the focal length of a lens is the distance from the lens to the focus. But he gave a full grade when he said it was the distance from the lens to the principal focus even though he did not define principal focus and might not have known what the term means. He gave a full grade when the student evidenced in any way that he had parallel rays in mind, whether he said that the rays must be parallel, or that the object must be far away, or simply drew a figure showing parallel rays and locating the focus. The student was not required to say anything about the optical center of a lens.

The student was given a grade of five on the third question when he said that "the specific heat of a substance is .113 when that amount of heat is required to heat it one degree." A strict grader would give zero on such a definition.

It is true, of course, that the majority of the students on these

examinations were from Indiana high schools, and that the results apply particularly to the State of Indiana. There is no occasion, however, for some of her sister states swelling with pride over the record made by their students. The number of high school graduates from some other states who took the examination was sufficiently large to warrant the statement that their grades averaged about the same as those made by graduates of Indiana high schools.

Let me say, further, that there is no occasion for teachers of other subjects to disparage the work of their colleagues in physics. The high school student gives far more time to English and mathematics than to physics. The papers returned on these examinations show that a considerable per cent of our high school graduates can not write intelligible English, that they do not reason, and that they can not apply the simplest mathematics to the solution of a physics problem of the simplest kind. These are strong statements and ones that the writer dislikes to make. He would not make them had not their truth been forced on him by the results of this examination. The writer will give to substantiate them but a few of hundreds of illustrations that might be given.

What does one think of the reasoning ability of 115 students who found the length of a 100 foot iron bridge to be more than 2,000 feet when the temperature rises 20 degrees; of the 7 students who found the bridge to be over 200,000 feet long at 20°; of the mathematics of 80 students who could not place the point when multiplying by the decimal in question 2?

What should one think of the reasoning ability and the practical knowledge of the 147 students who found that 4,400 amperes would be required to operate a 40 watt lamp; of the 43 who said it would require a current of 4,400 volts; of 200 others whose answers to this problem varied between 2 4-11 and (4400) 2² amperes *or volts*. One in seven expressed the current in volts, although the problem itself gives the voltage. Nineteen gave the current in ohms.

Take the answers to some of the questions as an illustration of unintelligible English:

Question 3.

"The heat at which it is most dense."

"It means that iron will expand at a certain temperature .113."

"The greatest heat without melting."

"It means that iron gives off a specific heat of .113 at normal temperature."

"It will take the same amount of heat acting on equal amounts of iron and water will heat the iron .113 calories more."

"Per cent of least retaining power."

"It is the heat where the molecules stop vibrating because they get so cold they don't move fast enough to keep moving very long time."

"The degree of temperature iron expels."

"Iron has that heat for chemical use."

"Amount of heat iron will stand before it will expand."

"The natural temperature of iron."

"The amount of heat in one square inch."

Question 5.

"Pail blue."

"The color would be a mixture of red and blue like a rainbough."

Question 6.

"It is 8 ins. to the first focus and every other one gains eight from the proceeding one."

"The lens will increase the distance of natural eyesight by 8 inches."

"Its exactness is for 8 inches is precise."

"Light looks same as normal 8 inches from lens."

"8 inches in width of light."

"Lens 8" long."

"Four years is to long to remember these questions studied one simes-ter."

Question 7.

"When the beam of light passes between two mediums the refraction is caused by the beam striking the horizontal side of the angle of refraction (or conversely) and being refracted off at rt. \angle -s at side it first strikes."

"Particles of dust in the mediums."

"The refraction is caused by striking the rays of light to the surface of an object the smother the surface the greater the refraction."

Question 8.

"It is a positive current."

"Five ohms is the current."

"The current would not be any as all of the volt would be used up in the ohms."

Question 9.

"Alternating current" (40 students gave this answer).

"The current would half to be 40 wats to make the bulb look normal."

"The current would be only 40 watts for the rest of it more than 40 watts would be held in the storage battery."

Question 10.

"The dynamo takes up as much energy—friction as used in running the dynamo; which when connected to act on another object will give it that amount of force, cause it to move proportionally."

"The brushes meet with the contact points of the armiture which are magnitized and then the break comes."

"The friction of the brushes unites with the lines of force and attracts into the wires where the electricity leaves the magnits and runs into the cables connected to the transformers."

"I do not know anything pretending to this question."

"It is generated by two or more coils of wire have currents where one has more power to overcome the resistance of the other which by other appliances it produces a electrol motive force."

"By the friction of magnates."

"Archimedes principal."

Table VIII brings us back to the question which occasioned this study—do college students who have had high school physics make better grades in their college physics class than are made by those who have had no previous work in the subject? The column "College grade" gives the average physics grade

made the first term or semester by the number of students noted in the column "Number," at the institution listed in the first column.

TABLE VIII.

EFFECT OF HIGH SCHOOL PHYSICS ON COLLEGE GRADES.

Institution	One year of high school physics		No high school physics	
	Number	College grade	Number	College grade
Central Normal College	4	87.0	7	85.1
De Pauw University.....	21	86.5	7	83.2
Earlham College.....	14	80.0	8	78.0
Indiana University.....	235	71.9	66	67.6
Rose Polytechnic Institute.....	65	80.1	21	76.3
Indiana State Normal	17	82.5	4	88.5
Valparaiso University	10	73.5	1	67.5
Wabash College.....	26	70.7	5	70.0
Weighted Average.....	392	77.7	119	72.6

The general agreement of the data shows that the results are not accidental. The reader will draw his own conclusions. The conclusions of the several college men co-operating in this study, to all of whom advance copies of this paper were sent, are expressed with more or less definiteness in the following comments, taken from letters to the writer in answer to a request for an opinion:

"Personally, I have not been able to see much difference in the grades of students who have had high physics and those who have not. In many instances the student who comes to the work without any previous study, works better than the others."

"The value of high school work in physics depends upon who teaches the subject and the spirit of the school. Sometimes the work is of great value, sometimes worse than useless. On the average, the showing is disappointing."

"For a long time I have been certain that our students bring no physics with them when they enter my classes. I am sometimes uncertain of the amount they take away. Of course, we do not conclude that the physics taken by the high school students was of no value, or that all of the teaching was bad. Students do not work hard enough nor in an efficient manner. Is not the fault largely due to the lack of seriousness on the part of students? Many are content so long as they 'get by.'"

"In my opinion, the difference in the grades is a fair argument in favor of dropping the work in physics in the high schools. The difference does not warrant the extra time put in, and might be better spent in the study of elementary mathematics or some allied subject."

"So far as the knowledge of physics is concerned, my students who have had high school physics do no better work than those who have not had it. The personality and the training of the high school teachers are factors which largely determine the amount of knowledge that the student acquires."

"Do the students in our high schools learn anything except dancing and basket ball?"

"It is indeed disappointing that our present high school teaching of physics is shown to be such a complete failure. I should hate, however, to have the problem of high school physics solved by dropping the subject from the curriculum. It seems to me that a better solution would be to require a far higher grade of preparation for those who are allowed to teach the subject. It seems to be the weak teachers who are lowering the grade of the work done throughout the state."

"The study confirms my view that the benefit derived from high school physics is discouragingly small. However, I believe that the gratifying results obtained in some schools justify an effort to bring the weak schools up to this standard."

"Though I have never made a very accurate study of the matter, I have never been able to see that previous high school training has made much difference in the grades made by university students of the subject. I am not sure that the fault is with the teaching so much as with the attitude of pupils toward any sort of serious work in the schools at the present time. Other teachers are complaining about the character of the high school work as much as we physicists. All the teachers are not incapable, of course, so the trouble can not be laid entirely on the teachers. There is too much interest in everything but study—basket ball, society, dramatics, and everything but sincere work. And it is all made the first thing by the pupils and fostered and encouraged by the parents. I do not see what is to be the outcome of it as yet, but certainly it can not go on in this way and to the extremes that it has gone, if education is to mean anything in the future."