A PLEA AGAINST OVER-STANDARDIZATION IN SCIENTIFIC EDUCATION.

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We who spend our days in the study and application and teaching of science like to feel and believe in the absolute definiteness of things. Laws are thus and so. Changes of chemical or physical nature follow perfectly definite courses, which can be predicted if we are in possession of sufficient data and knowledge of premises. Principles of nature are immutable and it is our chief business to further the study and understanding of these principles, so that they may be utilized to the benefit, rather than neglected to the harm, of mankind.

This is quite right. And research, application and teaching constitute the trinity of activities necessary for carrying out this ideal program. To discover more of that which is now hidden; to flood with light that which is now dark; to turn mysteries into commonplaces; to bring man into that mastery of Nature's habits which is necessary to give us association with her on equal terms, rather than domination by her, that is the work and pleasure of the scientific researcher. To apply this mass of knowledge of what nature may do for us, in the concrete use and proper direction of natural law—such is the life work of him who devotes himself to applied science. And to put order and intelligibility into all of this, so that the neophyte may be interested and efficiently trained; to make clear the path for coming generations to follow, so that knowledge shall not die with its discoverer, such is the duty and the privilege of the teacher.

But if we thus attempt to classify and segregate these three groups of scientists, we shall soon find that neither this classification nor any other can be successfully supported.

What researcher of any effectiveness but has visions of his work bearing fruit in changed conditions of life or in increased comfort and lightened burdens of humanity, and desire and some ability in the communication of his discoveries to the world?

And what inventor or worker in applied science is there whose power of observation is not constantly yielding new food for thought, or who is not, in some degree, a teacher of his fellows?

And, finally, how can a teacher successfully impart inspiration and scientific knowledge to youth in the school and colleges and universities, if he has nothing to do with some activity in uncovering the as yet unperceived truths of his science, or if he has not some desire, fulfilled directly or indirectly, even though always imperfectly, to apply these truths? He is, as Charles Dickens says of the guide-post, always pointing the way, but never going there, thus, perhaps, a very successful guide-post, for those who have occasion to make inquiry, but a very indifferent teacher.

We have thus the paradox of a science which is all order and rigid system, in the service of which are men whose mentalities and modes of thought and work are not subject to order or systematic classification

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according to any known rules. Were it not so, life would be a very drab affair. When the time comes (if it has to come) that character and personality, knowledge and enthusiasm are to be blocked out with compass and ruler, when reflection and reason and mental creativeness can be run through the "qualitative scheme" and labeled with all of the appropriate prefixes and suffixes and according to approved standardized spelling, we shall then be living in a colorless and tasteless and odorless world, to be sure.

Not only is it not possible to standardize human life and endeavor, it is an absolutely unthinkable proposition. But we are constantly trying to do this with our educational system, which has so much to do with the shaping of life. The very word "system" implies as much. We must agree upon methods of teaching. We must agree upon text books, if possible, and all use the standard system of books. We should standardize the length and content of our courses, the number of hours to be spent in administering them and, by the student, in studying them, the kind of preliminary examinations to be administered to candidates for education, the principles to be used in grading examination papers, the number of "experiments" or "unknowns" or "subjects" to be required of the student, and the number of years that the work of this system shall be followed (pursued or taken, according to the point of view), and so on and so forth.

Whether the lecture system is a failure or is not a failure—that is a question that has long been debated. We should like very much to know, so that we could definitely adopt it or rule it out, for our standard courses in science. I should say that the lecture system is a failure, and that it is not a failure, just as will be the case as long as it is used, and just as will be the case with every other system that ever will be tried. It is a failure in one class because the professor's conception of a lecture is to exhibit to his students the dry-bones of science in all of their inhuman nakedness, and without a particle of living flesh to cover them. Or else he recounts, with infinite pains and with absolute fidelity, the lessons exactly as they are found in some text book or in his notes. In which case his class room becomes the abiding place of boredom.

The system is a success in another class because this professor is able to remember when he, himself, was a student. He knows that his students are unlikely to learn much from the spoken lecture unless they first become interested and that one is not easily interested in anything that is presented only in its ugliest and most uninteresting aspect. He is able to lead his students to think, and to generate in them the will to extend their study outside the class room, while the other can teach effectively only by hearing required recitations on assigned lessons.

I think that the most naïve argument for standardization of chemical education that I have heard is this: that it is highly desirable that when a student goes from one college to another, or from a college to a university, he shall be able to "make connection" with the least possible loss of time or effort. "Chemistry," "taxonomy," "optics" and other such names shall mean, then, just the same thing in one place as in

another, in high-brow East or uncouth West, in "liberal arts" or "technical" college.

A certain amount of standardization is, of course, necessary and desirable. We must utilize the current conception of "clock hours" and the same conventional calendar of days, months, semesters and years (astronomical movements knowing no favorites), from which naturally follow "semester hours", "credits", "courses" and "graduation", also even "degrees". This is not objectionable, it is necessary and desirable, as I have just said. We should have some sort of definite notion of what four years of college work and any specified number of years of university work is to mean, in the matter of opportunities. But there is no sort of possibility of measuring the *results* of these opportunities by saying that the student has "had" or "taken" or "pursued" certain named courses or has received certain named degrees, unless you further specify where and how the opportunities were found. Not "where" in the geographical sense, nor with reference to the name of the school or the character of its traditions or the prowess of its football teams, but in the sense of the character and ability and enthusiasm of its teachers. The age of the school, the style of its architecture, the wealth of material equipment mean nothing, or so nearly nothing that they may be ignored, unless the men and women who constitute the soul of the institution in the form of its teaching staff are those who carry their students irresistibly into the swing of their own enthusiasms, so that the hard work which is involved in education and scientific training becomes recognized as a rare opportunity and a real pleasure.

Let me say here, with as much appearance of boldness as possible, that I do not want to standardize college teaching very far beyond elementary mechanical particulars; largely because it cannot be done. Let us suppose that two men are giving instruction to their respective classes in the same building. Let the classes be so assorted that their general characteristics are well balanced in the two divisions. Let the professors teach the same lesson, using the same text book and (let me carry the illustration to the extreme of absurdity) even saying the same words.

What is the result? One group of boys comes from the room at the end of the period, enthused, wideawake, refreshed from the hour's experience, with the consciousness of some new step taken in the delightful progress toward scientific understanding and with pleasurable anticipation for the next day's work. The other group comes out soured, disgruntled, pessimistic toward the whole question of education, and cynical and rebellious toward the arbitrary requirements of the college. What is the reason? Nothing any more difficult to understand than this: that different men were doing the teaching. The students absorbed what was about them. They caught the contagion that was in the air.

Have I not mentioned what we all know to be a perfectly familiar state of affairs and need I elaborate upon this topic? I shall do so only to the extent of saying that the unsuccessful teacher may have been intentionally following an absolutely correct and approved system

of teaching, while the other may or may not have been conscious that he was following any system. The difference was in the men themselves and this difference must always exist. I am not saying that the poor teacher should not study to improve, not his method or system, but his *results*. But that must be done by an entirely different process. It may even not be done at all, in which case this man should give up teaching and seek to acquire wealth in some other way.

What we must recognize is that there is a certain intangible something that makes men different from each other, that gives some the ability to do well that which others may do only poorly or not at all, and that this difference is nowhere more striking than in the world of the teacher. When we contemplate the numbers of individuals who have found their way into the ranks of college (nay, and of university) faculties, who have no ability whatsoever for teaching, who never can have any ability, and who are without vision or inspiration, even if we assume (as we may if we have sufficient optimism) that the lazy and indifferent teachers are usually weeded out—even then, what a sight it is and what a thought it is that so many young men and women have to lose the only opportunity for an education that they ever will have, simply because they chose the wrong college, or the wrong course in the right college, or the wrong class and the wrong teacher in the right course in the right college.

There should not be any such thing as a wrong and right college, course or teacher, except as this may be understood to refer to the innate fitness or unfitness of a student for a given kind of work. Certainly it should not be that the purposes of scientific (or other) education should be thwarted by having our science faculties poisoned by the presence of incompetent or uninspired teachers. But this does not point to standardization. It points in exactly the opposite direction. It means that the state of affairs should be such that no matter where the student goes, whether from intelligent choice or from fancy or necessity, he shall be placed under the guidance and oversight of men and women who know their subjects, who believe in their work and whose whole efforts are in the furtherance of interest in and understanding of the kind of knowledge which they are charged with teaching, *but each of whom gives to his students something that he alone can give.*

When this shall be so, every student (if he be a real student) will find a great opportunity, no matter what college or university he may choose and no matter what particular teacher may come to him as his drawing in the lottery of college "assignments". His opportunity will be different from that of another student who has gone to another school or who has drawn another teacher, but so it should be.

Have you ever considered what it is that makes the meetings of our scientific societies such a rare pleasure to all of us? Is it not the contact of mind with other minds and of character with other character? Is it not the exhilaration which is the product of the reaction upon our own mental habits of the mental habits of others whose interests are similar to ours but whose ways are different? And when we gather at our alumni dinners do we not dwell, more than upon any other topic, upon the special characteristics of the various teachers under whom we

have sat in the past? Imagine! Would it not be a pleasant occasion if each of those teachers had taught the same things in the same way as did all other teachers of like subjects, so that one might drift from one class to another "without losing any time in the process"? And would our society meetings not be charming little affairs if we had all been turned out of such a perfect system so that, mentally speaking, we should be like the little cast-iron kewpies that our engineering college foundry makes by the thousands to give to visitors as souvenirs?

A committee of the American Institute of Chemical Engineers has recently made a comprehensive survey of the curricula of a large number of American colleges who give work in chemical engineering. The results are extremely interesting and there is no doubt that they will be useful, as well, to those who are charged with the planning of such curricula. It is well that we should exchange ideas to the greatest possible extent, to the end that human experience shall be utilized in this, as in other tasks of similar nature.

One thing that is shown very strikingly is that nobody seems to know very definitely just what a "chemical engineer" really is and that nobody appears to have arrived at a very convincing definition of what should be called "chemical engineering", at least so far as this term applies to curricula leading to a specified degree. Such conceptions appear to range all the way from engineering with a smattering of chemistry to chemistry with a smattering of engineering, and from a supreme emphasis upon scientific fundamentals to a like emphasis upon plant practice, with every intermediate degree of opinion represented.

After all, why should this condition of affairs not be a reasonable expectation? To the extent that these differences in emphasis result from different grades of teaching success in the various departments, they are natural and inevitable. They are even desirable, if not overdone. In one institution, let us say, is a commanding figure at the head of the faculty of physics. He is not only a well trained scientist, able to give authoritative information along the lines of his own specialty, but he is likewise a man of splendid idealism and of outstanding ability as a teacher, eminently successful in his contact with students. He is familiar with the value of his science as applied to the industries and he is apt and energetic in acquainting his students with the principles of such applications. His colleagues will, very likely, be inspired with his spirit and his department will be inclined to develop, in personnel and in methods of work, to outstanding eminence. This department will then be known, on and off the campus, as a very desirable and profitable place to study.

In the same hypothetical institution the work of certain other departments may be of mediocre character, not because of the lack of that much to be desired "material equipment" but because of the lack of human qualities necessary for building really meritorious courses of instruction. As to the divisions of work within the departments, the situation may be similar to that which we have imagined as between departments.

The natural result, in this hypothetical institution, is a general leaning toward the kind of work administered in the department or the division which is dominated by the spirit and enthusiasm and ability of these hypothetical professors. At least this *should* be the natural result and it will be if the general oversight of the institution and of its curricula is in the hands of men of broad vision and purpose, whose planning goes beyond the ideas of credits, hours and standard courses, to ultimate effects upon the training of students for useful and happy lives in the scientific industries and research laboratories. Unfortunately this is not always the case. The crime of visiting petty annoyances upon this or that too successful teacher and of undermining his work in order to attain the impossible result of magnifying the work of another by comparison, or of withholding support from this or that too successful department, is still being perpetrated, to a greater or less extent, in most of our colleges. And what a tragedy of wasted years and means, and of baffled and disappointed youthful ambition it is, that so many of our young men, through no fault of their own (unless ignorance of the fate that awaits them may be considered a fault) find themselves in colleges and courses and classes where the best that they are likely ever to acquire is a precocious cynicism, a pessimistic philosophy whose cardinal principle is to "get by" the professor, the college and the world.

Is it any wonder that a student, thus disillusioned, turns with relief to the hectic pleasures of the jazz parlors or to the gladiatorial combat of the football field, or that he sometimes applies this same cynical philosophy to the latter enterprise? Here, at least, energy and enthusiasm find an outlet in endeavor that has a chance to win some sort of reward and approval. Perspiration and mental struggle may even earn the satisfaction of public applause, whereas in such classrooms as these there is no satisfaction or sense of accomplishment, other than that represented by certain marks in the professor's class book and on the cards of the Registrar.

If we should now go to another college we should find a similar state of affairs, with the exception that the emphasis might here be in some other direction, which would again depend upon the characteristics of the individuals of the department faculties within that school. All of these differences in emphasis would show very strikingly in a chart of hours devoted to typical subjects within the curriculum.

These are merely two illustrations, selected entirely at random and of purely hypothetical character. Let us extend the list and we shall have a situation, not merely common but almost universal, of colleges in which the work of the various curricula and departments, and of the various divisions within the departments, is not well balanced, or does not appear to be well balanced, simply because of innate differences in the minds of men. Where this lack of balance is the result of conditions such as I have outlined, it is a very grave mistake to attempt to correct it by subtracting from the work or influence of apparently over-emphasized departments, or of successful individual teachers within these departments. The inevitable result is a destruction of whatever merit the curriculum might originally have possessed. Such correction must begin with a real upbuilding of the deficient depart-

ments or courses, not simply by throwing increased financial support to their material equipment but by improvement in personnel. This (if my observation is a reliable indicator) is one of the most perplexing problems of college management. Too many presidents and deans apparently lack the courage to get rid of incompetent and mischievous teachers, especially when the latter form a part of an internal political system that is hard to break. But it is the only real solution.

If, then, it were possible to standardize scientific education to the *n*th degree, if it were possible (as it never will be) for us to come to unanimous agreement as to length, content and sequence of courses, upon method of presentation, upon text books and examinations and grading and degrees, we should be very little nearer a statement of what effective training in science should be. For we should still have, as I hope we always shall have, those personal differences in the characteristics of the teachers of all of our colleges which break up, in such a human and delightful manner, the mechanical routine of study and class work and which give, or should give, every alumnus of every college some ground for boasting of the excellence of his own alma mater. And upon these differences, to a very considerable degree, must be based the practical distribution of work in a given curriculum.

As individuals and as faculties we believe in and fight for academic freedom. And that is right. Let us understand that this idea shall include the freedom to throw our individual selves into our teaching and the assurance that our tenure and the moral and material support we receive shall not depend upon any views upon political, religious, economic or ethical questions we may hold and express, so long as these are sincere, or upon personal favor of any kind, but upon the results of our teaching, viewed in the broadest possible way.

In this paper and elsewhere I have repeatedly dwelt upon the importance of good teaching. I believe that the mechanics of courses and curricula, of quizzes and examinations, of honors and degrees, are of very vital importance and it is necessary that they should be worked out in the most intelligent manner possible, to the end that some degree of uniformity should attend our various and united efforts to train our young men and women for careers in the work of science. But machinery, however perfect, will not run itself. You may have a mammoth educational plant, an all but ideal equipment of machinery and apparatus and materials, and your courses and curricula may be planned with the utmost skill, but if the soul of the institution is non-existent there will be no education that is worth a fragment of the cost. As I have already indicated, the soul of the college, of the university, is its teaching staff and no amount of mechanical standardization is going to develop a soul. Not only this but too much standardization will inevitably cramp and destroy such a soul. A teacher must, of necessity, be well prepared in the subject which he undertakes to teach but he must also be a born teacher, loving his work, feeling its importance and taking infinite pleasure in observing its effects upon the scientific ideas and ideals developing in the minds of his students. And he must have originality and spontaneity. Otherwise he is a foreordained failure.

This plea, then, is not against standardization but against over-emphasis upon standardization. I am not arguing for chaos in scientific education. But I do plead for the highest possible degree of individualism in teaching. The relations between student and professor are not susceptible to any sort of standardization. The appeal of mind to mind must be a matter for individual development and the question of just what is to be taught, and how, cannot be decided wholly upon the basis of teaching system, or of clock-hours, credits, courses or semesters.

We must not make a fetish of system. Why, I have heard members of a college faculty argue with energy, and even passion, for insistence upon the minutest details of their courses as they had developed them. One might suppose that the routine of their semester's work had somehow come down from Sinai, along with the thou-shalt-nots, or that "eighteen-weeks-three-times-per-week" were one of the established laws of nature.

Our problem must include a solution of personal equation. It might easily be that the two extremes of opinion, as represented in the educational survey to which I have already referred, will turn out graduates about equally useful and equally qualified to represent that somewhat nebulous individual, the "chemical engineer", if these extremes of development have followed as a natural consequence of the presence of conspicuous ability in the departments represented by these extremes. It is too much to suppose that this is always the case. We should indeed be living in an educational Utopia if it were the case. But to just the extent that such apparently one-sided development is due to the policy of rewarding conspicuous teaching success by increased teaching opportunities, and not to the operation of "pull" or personal favor or politics, to such an extent will our scientific education be rewarded by outstanding achievement on the part of our teachers and of our graduates. When this shall be the case we shall forget much of our worries about standardization.