Brain Work and Manual Work

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In olden times, men of science, and especially those who have done most to forward the growth of natural philosophy, did not despise manual work and handicraft. Galileo made his telescopes with his own hands. Newton learned in his boyhood the art of managing tools; he exercised his young mind in contriving most ingenious machines, and when he began his researches in optics he was able himself to grind the lenses for his instruments and himself to make the well known telescope which, for its time, was a fine piece of workmanship. Leibnitz was fond of inventing machines: windmills and carriages to be moved without horses preoccupied his mind as much as mathematical and philosophical speculations. Linnaeus became a botanist while helping his father – a practical gardener – in his daily work. In short, with our great geniuses handicraft was no obstacle to abstract researches – it rather favored them. On the other band, if the workers of old found but few opportunities for mastering science, many of them had, at least, their intelligences stimulated by the very variety of work which was performed in the then unspecialized workshops; and some of them had the benefit of familiar intercourse with men of science. Watt and Rennie were friends with Professor Robison; Brindley, the road-maker, despite his fourteen-pence-a-day wages, enjoyed intercourse with educated society, and thus developed his remarkable engineering faculties; the son of a well-to-do family could 'idle' at a wheelwright's shop, so as to become later on a Smeaton or a Stephenson.

We have changed all that. Under the pretext of division of labor, we have sharply separated the brain worker from the manual worker. The masses of the workmen do not receive more scientific education than their grandfathers did; but they have been deprived of the education of even the small workshop, while their boys and girls are driven into a mine, or a factory, from the age of thirteen, and there they soon forget the little they may have learned at school. As to the scientists, they despise manual labor. How few of them would be able to make a telescope, or even a plainer instrument? Most of them are not capable of even designing a scientific instrument, and when they have given a vague suggestion to the instrument-maker they leave it with him to invent the apparatus they need. Nay, they have raised the contempt of manual labor to the height of a theory. "The scientist," they say, "must discover the laws of Nature, the civil engineer must apply them and the worker must execute in steel or wood, in iron or stone, the patterns devised by the engineer. He must work with machines invented for him, not by him. No matter if he does not understand them and cannot improve them: the scientist and the scientific engineer will take care of the progress of science and industry."

It may be objected that, nevertheless there is a class of men who belong to none of the above three divisions. When young, they have been manual workers, and some of them continue to be; but, owing to some happy circumstances, they have succeeded in acquiring some scientific knowledge, and thus they have combined science with handicraft. Surely there are such men; happily enough there is a nucleus of men who have escaped the so-much-advocated specialization of labor, and it is precisely to them that industry owes its chief recent inventions. But they are the exceptions; they are the irregulars – the Cossacks who have broken the ranks and pierced the screens so carefully erected between the classes. And they are so few, in comparison with the ever-growing requirements of industry and of science as well, as I am about to prove – that all over the world we hear complaints about the scarcity of precisely such men.

What is the meaning, in fact, of the outcry for technical education which has been raised at one and the same time in this country, in France, in Germany, in the States, and in Russia, if it does not express a general dissatisfaction with the present division into scientists, scientific engineers, and workers? Listen to those who know industry, and you will see that the substance of their complaints is this: The worker whose task has been specialized by the permanent division of labor has lost the intellectual interest in his labor, and it is especially so in the great industries: he has lost his inventive powers. Formerly, he invented very much. Manual workers – not scientists nor trained engineers-have invented, or brought to perfection, the prime motors and all that mass of machinery which has revolutionized industry for the last hundred years. But since the great factory has prevailed, the worker, depressed by the monotony of his work, invents no more. What can a weaver invent who merely supervises four looms, without knowing anything either about their complicated movements or how the machines grew to be what they are? What can a man invent who is condemned for life to bind together the ends of two threads with the greatest celerity, and knows nothing beyond making a knot? At the outset of modern industry, three generations of workers *have* invented; now they cease to do so. As to the inventions of the engineers, specially trained for devising machines, they are either devoid of genius or not practical enough. Those 'nearly to nothings' of which Sir Frederick Bramwell spoke recently at Bath are missing in their inventions – those nothings which can be learned in the workshop only, and which permitted a Murdoch and the Sohe workers to make a practical engine of Watt's schemes. None but he who knows the machine – not in its drawings and models only, but in its breathing and throbbings – who unconsciously thinks of it while standing by it, can really improve it. Smeaton and Newcomen surely were excellent engineers; but in their engines a boy had to open the steam valve at each stroke of the piston; and it was one of those boys who once managed to connect the valve with the remainder of the machine, so as to make it open automatically, while he ran away to play with other boys. But in the modern machinery there is no room left for naive improvements of that kind. Scientific education on a wide scale has become necessary for further inventions, and that education is refused to the workers. So that there is no issue out of the difficulty unless scientific education and handicraft are combined together – unless integration of knowledge takes the place of the present divisions. Such is the real substance of the present movement in favor of technical education. But, instead of bringing to public consciousness the, perhaps, unconscious motives of the present discontent, instead of widening the views of the discontented and discussing the problem to its full extent, the mouthpieces of the movement do not mostly rise above the shopkeeper's view of the question. Some of them indulge in jingo talk about crushing all foreign industries out of competition, while the others see in technical education nothing but a means of somewhat improving the flesh-machine of the factory and of transferring a few workers into the upper class of trained engineers.

Such an ideal may satisfy them, but it cannot satisfy those who keep in view the combined interests of science and industry, and consider both as a means for raising humanity to a higher level. We maintain that in the interests of both science and industry, as well as of society as a whole, every human being, without distinction of birth, ought to receive such in education as would enable him, or her, to combine a thorough knowledge of science with a thorough knowledge of handicraft. We fully recognize the necessity of specialization of knowledge, but we maintain that specialization must follow general education, and that general education must be given in science and handicraft alike. To the division of society into brainworkers and manual workers we oppose the combination of both kinds of activities; and instead of "technical education," which means the maintenance of the present division between brain work and manual work, we advocate the *éducation intégrale,* or complete education, which means the disappearance of that pernicious distinction. Plainly stated, the aims of the school under this system ought to be the following: To give such an education that, on leaving school at the age of eighteen or twenty, each boy and each girl should be endowed with a thorough knowledge of science – such a knowledge as might enable them to be useful workers in science – and, at the same time, to give them a general knowledge of what constitutes the bases of technical training, and such a skill in some special trade as would enable each of them to take his or her place in the grand world of the manual production of wealth. I know that many will find that aim too large, or even impossible to attain, but I hope that if they have the patience to read the following pages, they will see that we require nothing beyond what can be easily attained. In fact, *it has been attained*; and what has been done on a small scale could be done on a wider scale, were it not for the economical and social causes which prevent any serious reform from being accomplished in our miserably organized society.

The experiment has been made at the Moscow Technical School for twenty consecutive years, with many hundreds of boys; and the testimonies of the most competent judges at the exhibitions of Brussels, Philadelphia, Vienna, and Paris are to the effect that the experiment has been a success. The Moscow school admits boys not older than fifteen, and it requires from boys of that age nothing but a substantial knowledge of geometry and algebra, together with the usual knowledge of their mother tongue; younger pupils are received in the preparatory classes. The school is divided into two sections – the mechanical and the chemical; but as I personally know the former only (it is also the more important in our case), so I shall limit my remarks to the education given in the mechanical section. Well, after a five or six years' stay at the school, the students leave it with a thorough knowledge of higher mathematics, physics, mechanics, and connected sciences – so thorough, indeed, that it is not second to that acquired in the best mathematical faculties of the best European universities. When myself a student of the mathematical faculty of the St. Petersburg University, I had the opportunity of comparing their knowledge with our own. I saw the courses of higher geometry compiled by some students of the technical school for the use of their comrades; I admired the facility with which they applied the integral calculus to dynamical problems; and I came to the conclusion that while we, university students, had more knowledge of a general character (for instance, in mathematical astronomy), they, the students of the school, were much more advanced in higher geometry, and especially in the applications of higher mathematics to the most intricate problems of dynamics, the theories of heat and elasticity. But, while we, the students of the university, hardly knew the use of our hands, the students of the school fabricated *with their own hands,* and without the help of professional workmen, fine steam-engines, from the heavy boiler to the last finely turned screw, agricultural machinery, and scientific apparatus-all for the trade – and they received the highest awards for the work of their hands at the international exhibitions. They were scientifically educated skilled workers-workers with university education-highly appreciated even by the Russian manufacturers who so much distrust science.

Now, the methods by which these wonderful results were achieved were these: In science, learning from memory was not in honor, while independent research was favored by all means. Science was taught hand in hand with its applications, and what was learned in the schoolroom was applied in the workshop. Great attention was paid to the highest abstractions of geometry as a means for developing imagination and research. As to the teaching of handicraft, the methods, were quite different from those which proved a failure at the Cornell University, and differed, in fact, from those used in most technical schools. The student was not sent to a workshop to learn some special handicraft and to earn his existence as soon as possible, but the teaching of technical skill was prosecuted -according to a scheme elaborated by the founder of the school, M. Dellavos, and now applied also at Chicago – in the same systematical way as laboratory work is taught in the modern universities. It is evident that drawing was considered as the first step in technical education. Then the student was brought, first, to the carpenter's workshop, or rather laboratory, and there he was thoroughly taught to execute all kinds of carpentry and joinery. No efforts were spared in order to bring the pupil to a certain perfection in that branch – the real basis of all trades. Later on, he was transferred to the turner's workshop, where he was taught to make in wood the patterns of those things which he would have to make in metal in the following workshops. The foundry followed, and there he was taught to cast those parts of machines which he had prepared in wood; and it was only after he had gone through the first three stages that he was admitted to the smith's and engineering workshops. Such was the system which English readers will find described in full in a recent work by Mr. [Chrales [Charles H.] Ham,[1] and which has been introduced, in its technical part, in the Chicago Manual Training School. As for the perfection of the mechanical work of the students, I cannot do better than to refer to the reports of the juries at the above-named exhibitions.

The Moscow Technical School surely is not an ideal school. It totally neglects the humanitarian education of the young men.

But we must recognize that the Moscow experiment – not to speak of hundreds of other partial experiments – has perfectly well proved the possibility of combining a scientific education of a very high standard with the education which is necessary for becoming an excellent skilled laborer. It has proved, moreover, that the best means for producing really good skilled laborers is to seize the bull by the horns – to grasp the educational problem in its great features, instead of trying to give some special skill in some handicraft, together with some scraps of knowledge in some branch of some science. And it has shown also what can be obtained, without over-pressure, if a rational economy of the scholar's time is always kept in view, and theory goes hand in band with practice. Viewed in this light, the Moscow results do not seem extraordinary at all, and still better restilts may be expected if the same principles are applied from the earliest years of education. Waste of time is the leading feature of our present education. Not only are we taught a

[1] *Manual Training: the Solution of Social and and Industrial Problems.* By Ch. H. Ham. London: Blackie & Son. 1886. I can add that like results have been achieved again at the Krasnoufimsk *Realschule,* in the province of Orenburg, especially with regard to agriculture and agricultural machinery. The achievements of the school, however, are so interesting that they deserve more than a short mention.

mass of rubbish, but what is not rubbish is taught so as to make us waste as much time as possible. Our present methods of teaching originate from a time when the accomplishments required from an educated person were extremely limited; and they have been maintained, notwithstanding the immense increase of knowledge which must be conveyed to the scholar's mind since science has so much widened its former limits. Hence the over-pressure in schools, and hence, also, the urgent necessity of totally revising both the subjects and the methods of teaching, according to the new wants and to the examples already given here and there, by separate schools and separate teachers.

It is evident that the years of childhood ought not to be spent so uselessly as they are now. German teachers have shown how the very play of children can be made instrumental in conveying to the childish mind some concrete knowledge in both geometry and mathematics. The children who have made the squares of the theorem of Pythagoras out of pieces of colored cardboard, will not look at the theorem, when it comes in geometry, as on a mere instrument of torture devised by the teachers; and the less so if they apply it as the carpenters do. Complicated problems of arithmetic, which so much harassed us in our boyhood, are easily solved by children seven and eight years old, if they are put in the shape of interesting puzzles. And if the *Kindergarten*-German teachers often make of it a kind of barrack in which each movement of the child is regulated beforehand-has often become a small prison for the little ones, the idea which presided at its foundation is nevertheless true. In fact, it is almost impossible to imagine, without having tried it, how many sound notions of nature, habits of classification, and taste for natural sciences can be conveyed to the children's minds; and, if a series of concentric courses adapted to the various phases of development of the human being were generally accepted in education, the first series in all sciences, save sociology, could be taught before the age of ten or twelve, so as to give a general idea of the universe, the earth and its inhabitants, the chief physical, chemical, zoological, and botanical phenomena, leaving the discovery of the *laws* of those phenomena to the next series of deeper and more specialized studies. On the other side, we all know how children like to make toys themselves, how they gladly imitate the work of full-grown people if they see them at work in the workshop or the building-yard. But the parents either stupidly paralyze that passion, or do not know how to utilize it. Most, of them despise manual work and prefer sending their children to the study of Roman history, or of Franklin's teachings about saving money, to seeing them at a work which is good for the "lower classes only." They thus do their best to render subsequent learning the more difficult.

And then come the school years, and time is wasted again to an incredible extent. Take, for instance, mathematics, which everyone one ought to know, because it is the basis of all subsequent education, and which so few really learn in our schools. In geometry, time is foolishly wasted by using a method which merely consists in committing geometry to memory. In most cases, the boy reads again and again the proof of a theorem till his memory has retained the succession of reasonings. Therefore, nine boys out of ten, if asked to prove an elementary theorem two years after having left the school, will be unable to do it, unless mathematics is their specialty. They will forget which auxiliary lines to draw, and they never have been taught to *discover* the proofs by themselves. No wonder that later on they find such difficulties in applying geometry to physics, that their progress is despairingly sluggish, and that so few master higher mathematics. There is, however, the other method which permits progress, as a whole, at a much speedier rate, and under which he who once has learned geometry will know it all his life long. Under this system, each theorem is put as a problem; its solution is never given beforehand, and the pupil is induced to find it by himself. Thus, if some preliminary exercises with the rule and the compass have been made, there is not one boy or girl, out of twenty or more, who will not be able to find the means of drawing ail angle which is equal to a given angle, and to prove their equality, after a few suggestions from the teacher; and if the subsequent problems are given in a systematic succession (there are excellent text-books for the purpose), and the teacher does not press his pupils to go faster than they can go at the beginning, they advance from one problem to the next with all astonishing facility, the only difficulty being to bring the pupil to solve the first problem and thus to acquire confidence in his own reasoning. Moreover, each abstract geometrical truth must be impressed on the mind in its concrete form as well. As soon as the pupils have solved a few problems on paper, they must solve them on the playing-ground with a few sticks and a string, and they must apply their knowledge in the workshop. Only then will the geometrical lines acquire a concrete meaning in the children's minds; only then will they see that the teacher is playing no tricks when he asks them to solve problems with the rule and the compass, without resorting to the protractor; only then wilt they *know* geometry. 'Through the eyes *and* the hand to the brain' – that is the true principle of economy of time in teaching. I remember as if it were yesterday, how geometry suddenly acquired for me it new meaning, and how this new meaning facilitated all ulterior studies. It was as we were mastering a Montgolfier balloon, and I remarked that the angles at the summits of each of the twenty strips of paper out of which the balloon was going to be made must cover less than the fifth part of a right angle each. I remember, next, how the sines and the tangents ceased to be mere cabalistic signs when they permitted us to calculate the length of a stick in a working profile of a fortification; and how geometry in space became plain when we began to make on a small scale a bastion with embrasures and barbettes – an occupation which obviously was soon prohibited on account of the state into which we brought our clothes. "You look like navvies," was the reproach addressed to us by our intelligent educators, while we were proud precisely of being navvies – and of discovering the use of geometry.

By compelling our children to study real things from mere graphical representations, instead of *making* those things themselves, we compel them to waste the most, precious time; we uselessly worry their minds; we accustom them to the worst methods of learning; we kill independent thought in the bud; and very seldom we succeed in conveying a real knowledge of what we are teaching. Superficiality, parrot-like repetition, slavishness and inertia of mind are the results of our education. We do not teach our children how to learn. The very beginnings of science are taught on the same pernicious system. In most schools, even arithmetic is taught in the abstract way, and mere rules are stuffed into the poor little heads. The idea of a unit, which is arbitrary and can be changed at will in our measurement (the match, the box of matches, the dozen of boxes, or the gross; the meter, the centimeter, the kilometer, and so on), is not impressed on the mind, and therefore, when the children come to the decimal fractions they are at it loss to understand them; whereas in France, where the decimal system of measures and money is a matter of daily life, even those workers who have received the plainest elementary education are quite familiar with decimals. To represent twenty-five centimes, or twenty-five centimeters, they write 'zero twenty-five,' while most of my readers surely remember how this same zero at the head of a row of figures puzzled them in their boyhood. We do also what we can to render algebra unintelligible, and our children spend one year before they have learned what is not algebra at all, but a mere system of abbreviations, which can be learned by the way, if it is taught together with arithmetic.

The waste of time in physics is merely revolting. While young people very easily understand the principles of chemistry and its formulas, as soon as they themselves make the first experiments with a few glasses and tubes, they mostly find the greatest difficulties in grasping the mechanical introduction into physics, partly because they do not know geometry, and especially because they are merely shown costly machines instead of being induced to make themselves plain apparatus for illustrating the phenomena they study. Instead of learning the laws of force with plain instruments which a boy of ten can easily make, they learn them from mere drawings, in a purely abstract fashion. Instead of making themselves an Atwood's machine with a broom-stick and the wheel of an old clock, or verifying the laws of falling bodies with a key gliding on an inclined string, they are shown a complicated apparatus, and in most cases the teacher himself does not know how to explain to them the principle of the apparatus, and indulges in irrelevant details. And so it goes on from the beginning to the end, with but a few honorable exceptions.[2]

If waste of time is characteristic of our methods of teaching science, it is characteristic as well of the methods used for teaching handicraft. We know how years are wasted when a boy serves his apprenticeship in a workshop; but the same reproach can be addressed, to a great extent, to those technical schools which endeavor at once to teach some special handicraft, instead of resorting to the broader and surer methods of systematical teaching. Just as there are in science some notions and methods which are preparatory to the study of all sciences, so there are also some fundamental notions and methods preparatory to the special study of any handicraft. [Franz] Reuleaux has shown in that delightful book, the *Theoretische Kinematik,* [Theoretical Kinematics] that there is, so to say, a philosophy of all possible machinery. Each machine, however complicated, can be reduced to a few elements – plates, cylinders, discs, cones, and so on – as well as to a few tools-chisels, saws, rollers, hammers, &c.; and, however complicated its movements, they can be decomposed into a few modifications of motion, such as the transformation of circular motion into a rectilinear, and the like, with a number of intermediate links. So also each hanidcraft can be decomposed into it number of elements. In each trade one must know how to make a plate with parallel surfaces, a cylinder, a disc, a square and a round hole; how to manage a limited number of tools, all tools being mere modifications of less than a dozen types; and how to transform one kind of motion into another. This is the foundation of all mechanical handicrafts; so that the knowledge of how to make in wood those primary elements, how to manage the chief tools in wood-work, and how to transform various kinds of motion, ought to be considered as the very basis for the subsequent teaching of all possible kinds of mechanical handicraft. The pupil who has acquired that skill already knows one good half of all possible trades. Besides, none can be a good worker in science unless be is in possession of good methods of scientific research; unless he has learned to observe, to describe with exactitude, to discover mutual relations between

[2] Take, for instance, the description of Atwood's machine in any course of elementary physics. You will find very great attention paid to the wheel, on which the axle of the pulley is made to lie; hollow boxes, plates and rings, the clock, and other accessories will be mentioned before one word is said upon the leading idea of the machine, which is to slacken the motion of a falling body by making a falling body of small weight move a heavier body which is in the state of inertia, gravity acting on it in two opposite directions. That was the inventor's idea; and if it is made clear, the pupils see at once that to suspend two bodies or equal weight over a pulley, and to make them move by adding a small weight to one of them, is one of the means (and a good one) for slackening the motion during the falling; they see that the friction of the pulley must be reduced to a minimum, either by using the two pairs of wheels, which so much puzzle the text-book makers, or by any other means; that the clock is a luxury, and the 'plates and rings' are mere accessories: in short, that Atwood's idea can be realized with the wheel of a clock fastened, as a pulley, to a wall, or on the top of a broomstick secured in a vertical position. In this case, the pupils will understand the *idea* of the machine and of its inventor, and they will accustom themselves to separate the leading idea from the accessories; while in the other case they merely look with curiosity at the tricks performed by the teacher with a complicated machine, and the few who finally understand it spend a quantity of time in the effort.

facts seemingly disconnected, to make hypotheses and to verify them, to reason upon cause and effect, and so on. And none can be a good manual worker unless he has been accustomed to the good methods of handicraft altogether. He must grow accustomed to conceive the subject of his thoughts in a concrete form, to draw it, or to model, to hate badly kept tools and bad methods of work, to give to everything a fine touch of finish, to derive artistic enjoyment from the contemplation of gracious forms and combinations of colors, and dissatisfaction from what is ugly. Be it handicraft, science, or art, the chief aim of the school is not to make a specialist, from a beginner, but, to teach him the elements of knowledge and the good methods of work, and, above all, to give him that general inspiration which will induce him, later on, to put in whatever he does a sincere longing for truth, to like what is beautiful both as to form and contents, to feel the necessity of being a useful unit amid other human units, and thus to feel his heart at unison with the rest of humanity.

As for avoiding the monotony of work which would result from the pupil always making mere cylinders and discs, and never making full machines or other useful thing, there are thousands of means for avoiding that want of interest, and one of them, in use at Moscow, is worthy of notice. It is not, to give work for mere exercise, but to utilize everything which the pupil makes, from his very first steps. Do you remember how you were delighted, in your childhood, if your work was utilized, be it only as a part of something useful? So they do at Moscow. Each plank, planed by the pupils is utilized, as a part of some machine in some of the other workshops. When a pupil comes to the engineering workshop, and he is set to make a quadrangular block of iron with parallel and perpendicular surfaces, the block has an interest, in his eyes, because, when he has finished it, verified its angles and surfaces, and corrected its defects, the block is not thrown under the bank – it is given to a more advanced pupil, who makes a handle to it, paints the whole, and sends it to the shop of the school as a *presse-papier.* The systematical, teaching thus receives the necessary attractiveness.[3]

It, is evident that celerity of work is a most important factor in production. So it, might be asked if, under the above system, the necessary speed of work could be obtained. But there are two kinds of celerity. There is the celerity which we see in a lace-manufactory; full-grown men, with shivering hands and heads, are feverishly binding together the ends of two threads from the remnants of cotton yarn in the bobbins; you hardly can follow their movements. But the very fact, of requiring such kind of rapid work is the condemnation of the factory system. What has remained of the human being in those shivering bodies? What will be their outcome? Why this waste of human force, when it could produce ten times the value of the odd rests of yarn? This kind of celerity is required exclusively because of the cheapness of the factory slaves; so let us hope that no school will ever aim at this kind of quickness in work. But there is also the time-saving celerity of the well-trained worker, and this is surely achieved best by the kind of education which we advocate. However plain his work, the educated worker makes it better and quicker than the uneducated. Observe, for instance, how a good worker proceeds in cutting anything-say apiece of cardboard-and compare his movements with those of in improperly trained worker. The latter seizes the cardboard, takes the tool as it is, traces a line in a haphazard way, and begins to cut; half-way he is tired, and when be has finished his work is worth nothing; whereas, the

[3] The sale of the pupils' work is not, insignificant, especially when they reach the higher classes, and make steam-engines. Therefore the Moscow school, when I knew it, was one of the cheapest in the world. It gave boarding and education at a very low fee. But imagine such a school connected with a farm school, which grows food and exchanges it at its cost price. What will be the cost of education then?

former will examine his tool and improve it if necessary; he will trace the line with exactitude, secure both cardboard and rule, keep the tool in the right way, cut quite easily, and give you a piece of good work. That is the true time-saving celerity, the most appropriate for economizing human labor; and the best means for attaining it is an education of the most superior kind. The great masters painted with all astonishing rapidity; but their rapid work was the result of a great, development of intelligence an imagination, of a keen sense of beauty, of a fine perception of colors. And that is the kind of rapid work which humanity is in need of.

Much more ought to be said as regards the duties of the school, but I hasten to say a few words more as to the desirability of the kind of education briefly sketched in the preceding pages. Certainly, I do not cherish the illusion that a thorough reform in education or in any of the issues indicated in my preceding papers, will be made as long as the civilized nation, remain under the present narrowly egotistic system of production and consumption. All we can expect, as long as the present conditions last, is to have some microscopical attempts at reforming here and there on a smalle scale – attempts which necessarily will prove to be far below the expected results, because of the impossibility of reforming on a small scale when so intimate a connection exists between the manifold functions of a civilized nation. But the energy of the reconstructive genius of society depends precisely upon the depths of its conception as to what ought to be done, and how; and the necessity of recasting education is one of those necessities which are most, comprehensible to all, and are most appropriate for inspiring society with those ideals, without which stagnation or even decay are unavoidable. So let us suppose that a community – a city, or a territory which has, at least, a few millions of inhabitants – gives the above-sketched education to all its children, without distinction of birth (and we *are* rich enough to permit us the luxury of such an education), without asking anything in return from the children but, what they will give when the they have become producers of wealth. Suppose such all education is given, and analyze its probable consequence. I will not insist upon the increase of wealth which would result from having a young army of educated and well-trained producers; nor shall I insist upon the social benefits which would be derived front erasing the present distinction between the brain workers and the manual workers, and from thus reaching the concordance of interest and harmony so much wanted in our times of social struggles. I shall not dwell upon the fullness of life which would result for each separate individual, if he were enabled to enjoy the use of both his mental and bodily powers; nor upon the advantages of raising manual labor to the place of honor it ought to occupy in society, instead of being a stamp of inferiority, as it is now. Nor shall I insist upon the disappearance of the present misery and degradation, with all their consequences – vice, crime, prisons, price of blood, denunciation, and the like – which necessarily would follow. In short, I will not touch now the great social question, upon which so much has been written and so much remains to be written yet. I merely intend to point out in these pages the benefits which science itself would derive from the change.

Some will say, of course, that to reduce the scientists to the *rôle* of manual workers would mean the decay of science and genius. But those who will take into account the following considerations probably will agree that the result ought to be the reverse-namely, such a revival of science and art, and such a progress in industry, as we only can faintly foresee from what we know about the times of the Renaissance. It has become a commonplace to speak with emphasis about the progress of science during the nineteenth century; and it is evident, that our century, if compared with centuries past, has much to be proud of. But, if we take into account, that most of the problems which our century has solved already had been indicated, and their solutions foreseen, a hundred years ago, we must admit that the progress was not so rapid as might have been expected, and that something hampered it. The mechanical theory of heat was very well foreseen in the last century by Rumford and Humphry Davy, and even in Russia it was advocated by Lomollosoff.[4] However, much more than half a century elapsed before the theory reappeared in science. Lamarck, and even Linnaeus, Geoffroy Saint-Hilaire, Erasmus Darwin and, several others were fully aware of the variability of species; they were opening the way for the construction of biology on the principles of variation; but here, again, half a century was wasted before the variability of species was brought again to the front; and we all remember how Darwin's ideas were carried on and forced on the attention of university people, chiefly by persons who were not professional scientists themselves; and yet in Darwin's hands the theory of evolution surely was narrowed, owing to the overwhelming importance given to only one factor of evolution. For many years past, astronomy has been needing a careful revision of the Kant and Laplace's hypothesis; but no theory is yet forthcoming which would compel general acceptance. Geology surely has made wonderful progress in the reconstitution of the paleontological record, but dynamical geology progresses at a despairingly slow rate; the theory of the igneous origin of granite and other unstratified crystalline rocks is still taught in the universities, although the field geologists cannot reconcile it with the contradictory facts, and they are abandoning it in Germany and Russia; while all future progress in the great question as to the laws of distribution of living organisms on the surface of the earth is hampered by the want of knowledge as to the extension of glaciation during the Quaternary epoch.[5] In short, in each branch of science a revision of the current theories as well as new wide generalizations are wanted. And if the revision requires some of that inspiration of genius which moved Galileo and Newton, and which depends in its appearance upon general causes of human development, it requires also an increase in the number of scientific workers. When facts contradictory to current theories become numerous, the theories must be revised (we saw it in Darwin's case), and simple intelligent workers in science are required to accumulate them.

Immense regions of the earth still remain unexplored; the study of the geographical distribution of animals and plants meets with stumbling-blocks at every step. Travelers cross continents, and do not know even how to determine the latitude nor how to manage a barometer. Physiology, both of plants and animals, psycho-physiology, and the psychological faculties of man and animals are so many branches of knowledge requiring more data of the simplest description. History remains a *fable convenue* [agreed fable] chiefly because it wants fresh ideas, but also because it wants scientifically thinking workers to reconstitute the life of past centuries in the same way

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[4] In an otherwise also remarkable memoir on the Arctic Regions.

[5] The rate of progress in the recently so popular Glacial Period question was strikingly slow. Already Venetz in 1821 and Esmarck in 1823, had explained the erratic phenomena by the glaciation of Europe. Agassiz came forth with the theory of glaciation of the Alps, the Jura mountains, and Scotland, about 1810; and five years later, Guyot had published his map, of the routes followed by Alpine boulders. But forty-two years elapsed after Venetz wrote before one geologist of mark (Lyell) dared timidly to accept his theory, even to a limited extent – the most interesting fact being that Guyot's maps, considered as irrelevant in 1845, were recognized as conclusive after 1863. Even now – half a century after Agassiz's first work – Agassiz's views are not yet either refuted or generally accepted. So also Forbes's views upon the plasticity of ice. Let me add, by the way, that the whole polemics as to the viscosity of ice is a striking instance of how facts, scientific terms, and experimental methods quite familiar to building engineers, were ignored by the scientists who took part in the polemics. If these facts, terms and methods were taken into account, the polemics would not have raged for years with no result. Like instances, to show how science suffers from a want of acquaintance with facts and methods of experimenting well known to engineers, florists, and so on, could be produced in numbers.

as Thorold Rogers or Augustin Thierry have done it for separate epochs. In short, there is not one single science which does not suffer in its development from a want of men and women endowed with a philosophical conception of the universe, ready to apply their forces of investigation in a given field, however limited, and having leisure for devoting themselves to scientific pursuits. In a community such as we suppose, thousands of workers would be ready to answer any appeal for exploration. Darwin spent almost thirty years in gathering and analyzing facts for the elaboration of the theory of the origin of species. Had he lived in such a society as we suppose, he simply would have made an appeal to volunteers for facts and partial exploration, and thousands of explorers would have answered his appeal. Scores of societies would have come to life to debate and to solve each of the partial problems involved in the theory, and in ten years the theory would have been verified; all those factors of evolution which only now begin to receive due attention would have appeared in their full light. The rate of scientific progress would have been tenfold; and if the individual would not have the same claims on posterity's gratitude as he has now, the unknown mass would have done the work with more speed and with more prospect for ulterior advance than the individual could do in his lifetime. Mr. Murray's dictionary is an illustration of that kind of work – the work of the future.

However, there is another feature of modern science which speaks more strongly yet in favor of the change we advocate. While industry, especially by the end of the last century and during the first part of the present, has been inventing on such a scale as to revolutionize the very face of the earth, science has been losing its inventive powers. Scientists invent no more, or very little. Is it not striking, indeed, that the steam-engine, even in its leading principles, the railway-engine, the. steamboat, the telephone, the phonograph, the weaving-machine, the lace-machine, the lighthouse, the macadamized road, photography in black and in colors, and thousands of less important things, have *not* been invented by professional scientists, although none of them would have refused to associate his name with any of the named inventions? Men who hardly had received any education at school, who had merely stolen the crumbs of knowledge from the tables of the rich; men who made their experiments with the most primitive means-the attorney-clerk Smeaton, the instrument-maker Wait, the engine-brakesman Stephenson, the jeweler's apprentice Fulton, the millwright Rennie, the mason Telford, and hundreds of others whose very names remain unknown, were, as Mr. Smiles justly says, "the real makers of modern civilization;" while the professional scientists, provided with all means for acquiring knowledge and experimenting, have invented little in the formidable array of implements, machines, and prime-motors which has shown to humanity how to utilize and to manage the forces of nature.[6] The fact is striking, but its explanation is very simple: those men – the Watts and the Stephensons – knew something which the *savants* do not know-they knew the use of their hands; their surroundings stimulated their inventive powers; they knew machines, their leading principles, and their work; they had breathed the atmosphere of the workshop and the buildingyard.

We know how the scientists will meet the reproach. They will say: "We discover the laws of Nature, let others apply them; it is a simple division of labor." But such a rejoinder would be utterly untrue. The march of progress is quite the reverse, because in a hundred cases against one the mechanical invention comes before the discovery of the scientific law. It was not the dynamical theory of heat which came before the steam-engine – it followed it. When thousands of engines

[6] Chemistry is, to a great extent, an exception to the rule. Is it not because the chemist is so much of the manual worker?

already were transforming heat into motion under the eyes of thousands of scientists, and when they had done so for half a century, or more; when thousands of trains, stopped by powerful brakes, were disengaging heat and spreading thousands of sparks on the rails at their approach to the stations; when all over the civilized world heavy hammers and perforators were rendering burning hot the masses of iron they were hammering and perforating – then, and then only, a doctor, Mayer, ventured to bring out the mechanical theory of heat with all its consequences; and yet the scientists almost drove him to madness by obstinately clinging to their mysterious caloric fluid. When every engine was illustrating the impossibility of utilizing all the heat disengaged by a given amount of burnt fuel, then came the law of Clausius. When all over the world industry already was transforming motion into heat, sound, light, and electricity, and each one into each other, then only came Grove's theory of the "correlation of physical forces." It was not the theory of electricity which gave us the telegraph. When the telegraph was invented, all we knew about electricity was but a few facts more or less badly arranged in our books; the theory of electricity is not ready yet; it still waits for its Newton, notwithstanding the brilliant attempts or late years. Even the empirical knowledge of the laws of electrical currents was in its infancy when a few bold men laid a cable at the bottom of the Atlantic Ocean, despite the warnings of the authorized men of science.

The name of "applied science" is quite misleading, because, in the great majority of cases, invention, far from being an application of science, on the contrary creates a new branch of science. The. American bridges were no application of the theory of elasticity; they came before the theory, and all we can say in favor of science is, that in this special branch, theory and practice developed in a parallel way, helping one another. It was not the theory of the explosives which led to the discovery of gunpowder; gunpowder was in use for centuries before the action of the gases in a gun was submitted to scientific analysis. And so on. The great processes of metallurgy; the alloys and the properties they acquire from the addition of very small amounts of some metals or metalloids; the recent revival of electric lighting; nay, even the weather forecasts which truly deserved the reproach of being 'unscientific' when they were started by an old Jack tar, Fitzroy – all these could be mentioned as instances in point. Of course, we have a number of cases in which the discovery, or the invention, was a mere application of a scientific law (cases like the discovery of the planet Neptune), but in the immense majority of cases the discovery, or the invention, is unscientific to begin with. It belongs much more to the domain of art – art taking the precedence over science, as Helmholtz has so well shown in one of his popular lectures – and only after the invention has been made, science comes to interpret it. It is obvious that each invention avails itself of the previously accumulated knowledge and modes of thought; but in most cases it makes a start in advance upon what is known; it makes a leap in the unknown, and thus opens a quite new series of facts for investigation. This character of invention, which is to make a start in advance of former knowledge, instead of merely applying a law, makes it identical, as to the processes of mind, with discovery; and, therefore, people who are slow in invention are also slow in discovery.

In most cases, the inventor, however inspired by the general state of science at a given moment, starts with a very few settled facts at his disposal. The scientific facts taken into account for inventing the steam-engine, or the telegraph, or the phonograph were strikingly elementary. So that we can affirm that what we presently know is already sufficient for resolving any of the great problems which stand in the order of the day – prime-motors without the use of steam, the storage of energy, the transmission of force, or the flying-machine if these problems are not yet solved, it is merely because of the want of inventive genius, the scarcity of educated men endowed with it, and the present divorce between science and industry. On the one side, we have men who are endowed with capacities for invention, but have neither the necessary scientific knowledge nor the means for experimenting during long years; and, on the other side, we have men endowed with knowledge and facilities for experimenting, but devoid of inventive genius, owing to their education and to the surroundings they live in – not to speak of the patent system, which divides and scatters the efforts of the inventors instead of combining them.

The flight of genius which has characterized the workers at the outset of modern industry has been missing in our professional scientists. And they will not recover it as long as they remain strangers to the world, amid their dusty bookshelves; as long as they are not workers themselves, amid other workers, at the blaze of the iron furnace, at the machine in the factory, at the turning lathe in the engineering workshop; sailors amid sailors on the sea, and fishers in the fishing boat, wood-cutters in the forest, tillers of the soil in the field. Our teachers in art, have repeatedly told us of late that we must not expect a revival of art as long as handicraft remains what it is; they have shown how Greek and medieval art were daughters of handicraft, how one was feeding the other. The same is true with regard to handicraft and science; their separation is the decay of both. As to the grand inspirations which unhappily have been so much neglected in most of the recent discussions about art – and which are missing in science as well – these can be expected only when humanity, breaking its present bonds, shall make a new start in the higher principle of human solidarity, doing away with the present duality of moral sense and philosophy.

It is evident, however, that all men and women cannot equally enjoy the pursuit of scientific work. The variety of inclinations is such that some will find more pleasure in science, some others in art, and others again in some of the numberless branches of the production of wealth. But, whatever the occupations preferred by everyone, everyone, will be the more useful in his own branch if he is in possession of its serious scientific knowledge. And, whosoever he might be – scientist or artist, physicist or surgeon, chemist or sociologist, historian or poet – he would be the gainer if he spent a part of his life in the workshop or the farm (the workshop *and* the farm), if he were in contact with humanity in its daily work, and had the satisfaction of knowing that he himself discharges his duties as an unprivileged producer of wealth. How much better the historian and the sociologist would understand humanity if they knew it, not in books only, not in a few of its representatives, but as a whole, in its daily life, daily work, and daily affairs! How much more medicine would trust to hygiene, and how much less to prescriptions, if the young doctors were the nurses of the sick and the nurses received the education of the doctors of our time! And how would gain the poet, in his feeling of the beauties of nature, how much better would he know the human heart, if he met the rising sun amid the tillers of the soil, himself a tiller; if he fought against the storm with the sailors on board ship; if he knew the poetry of labor and rest, sorrow and joy, struggle and conquest! *Greift nur hinein in's volle Menschenleben!* [Only reach into full human life!] Goethe said; *Ein jeder lebt's-nicht vielen ist's bekannt.* [Everyone lives - not many are known.] But how few poets follow his advice!

The so-called division of labor has grown under a system which condemned the masses to toil all the day long, and all the life long, at the same wearisome kind of labor. But if we take into account how few are the real producers of wealth in our present society, and how squandered is their labor, we must recognize that Franklin was right in saying that to work five hours a day would generally do for supplying each member of a civilized nation with the comfort now accessible for the few only, provided everybody took his due share in production. But we have made some progress since Franklin's times, not to say a word of further progress. More than one-half of the working day would thus remain to everyone for the pursuit of art, science, or any hobby he might choose to like; and his work in those fields would be the more profitable if he spent the other half of the day in productive work – if art and science were followed from mere inclination, not for mercantile purposes. Moreover, a community organized on the principles of all being workers would be rich enough to consider that every man and woman, after having reached a certain age – say, of forty or more-ought to be relieved from the moral obligation of taking a direct part in the performance of the necessary manual work, so as to be able entirely to devote himself or herself to whatever he or she chooses in the domain of art, or science, or any kind of work. Free pursuit in new branches of art and knowledge, free creation, and free development thus might be fully guaranteed. And such a community would not know misery amid wealth; it would not know the duality of conscience which permeates our life and stifles every noble effort. It would freely take its flight towards the highest regions of progress compatible with human nature. But it is not by resorting to such poor means as some training of the hand in a handicraft school, or some teaching of husbandry under the name of Slöjd, that great things are achieved. Great problems must be faced in their full greatness.

P. KROPOTKIN.

POSTSCRIPT.

Since the above was written I have had the pleasure of visiting the Gordon College at Aberdeen. There I found the system described in the preceding pages had been applied with full success, for some years, under the direction of Dr. Ogilvie. It is the Moscow, or Chicago, system on a limited scale.

While receiving substantial scientific education, the pupils are also trained in the workshops – but not for one special trade, as it unhappily too often is the case. They pass through the carpenters' workshop, the casting in metals, and the engineering workshop; and in each of these they learn the foundations of each of the three trades, sufficiently well for supplying the school itself with a number of useful things. Besides, as far as I could ascertain from what I saw in the geographical and physical classes, as also in the chemical laboratory, the system of 'through the hand to the brain,' and *vice-versa,* is in full swing, and it is attended with the best success. The boys work with the physical instruments, and they study geography in the field, instruments in hands, as well as in the class-room. Some of their surveys filled with joy my geographer's heart. It is evident that the Gordon College's industrial department is not a mere copy of any foreign school; on the contrary, I should permit myself to suggest that if Aberdeen has made that excellent move towards combining science with handicraft, the move was a natural outcome of what has been practiced long since, on a smaller scale, in the Aberdeen daily school.

Pëtr Kropotkin
Brain Work and Manual Work
1890

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