THE RUSSIAN SYSTEM OF SHOP-WORK INSTRUCTION FOR ENGINEERS AND MACHINISTS, J.D. RUNKLE 1876

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MASS. INSTITUTE OF TECHNOLOGY.

J. D. Runkle -

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OF

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FOR

ENGINEERS AND MACHINISTS.

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To the Corporation of the Mass. Institute of Technology:

GENTLEMEN: — It must be admitted that technological education is still in the experimental state. The methods in use, even in our primary schools, do not pass unquestioned, and upon the best methods of teaching the ancient languages, and the pure mathematics, subjects which have constituted the main elements in all high and generous culture for ages, the most learned doctors disagree. We could hardly expect, then, that the best methods of teaching the modern sciences should already have been found; and particularly the best way of working them out practically in the industrial arts. Ten years ago, when the courses in this Institute began, some valuable experience in teaching science had been gained. It had been found that simple text-book instruction in Chemistry, unaccompanied by corresponding laboratory work by the pupil, was comparatively useless; that a small professional laboratory, while good for an advanced specialist, was no place for a beginner; and, in short, it was too expensive to teach each pupil singly. Hence there had grown up, as a necessity, large and well arranged laboratories, especially adapted to the instruction of pupils in as large classes or sections as one or more teachers could instruct well at the same time. This step of teaching laboratory work to large classes of pupils, and all in about the

same state of progress, was found to be most economical for both parties, and the only system by which this element of instruction could be maintained with a large number of pupils. It has also been found by experience that general chemistry, quantitative and qualitative analysis, and the various departments of applied chemistry, can best be taught in laboratories adapted to each. Such are the steps which have been taught us by experience in a single department. But unfortunately, in hardly another department have we the same experience, and an equally well defined and systematic method of instruction. In architecture, in laboratory instruction in physics as a part of the required course of each candidate for a degree, in the mining and metallurgical laboratories for the working of ores in quantities, and in the laboratory for teaching the nature and use of steam, this Institute has the honor of having led the way. But in these cases each year's experience serves to suggest improvements in details, which add materially to the amount and quality of the work done.

While we have been gaining experience in these directions, other technical schools have also been working out, more or less fully, other phases of the same great educational problem upon which we are all engaged; each doing its work under such limitations and conditions, and in such main directions, as its location and other controlling circumstances have dictated. Each, therefore, owing to a great extent to these varying circumstances and conditions, has its lesson to teach to all the others; and it was with the expectation that the opportunity of learning some of these lessons would offer, that our Professors and Students made their recent visit to the International Centennial Exhibition at Philadelphia.

The Act of Congress of 1862, giving lands to the States for educational purposes, while not excluding other subjects, laid particular stress upon the two great industries upon which the well-being of any great community must always mainly depend, agriculture and the mechanic arts. While all the sciences having a direct application to these arts should be taught, there can be no doubt that it was also the intention that the arts themselves should be taught in the most practical and fundamental way; and accordingly, we find farms in several of the States, used in one or two

cases, simply as experimental stations, but in most cases conducted as model farms, and depending to a considerable extent upon the labor of the student, which is regarded as instruction, and is made a required part of the curriculum of the course in agriculture. In like manner many of these schools have already established shops for the instruction of their students in the mechanic arts.

As this Institute was selected by the State to represent the mechanic arts, for which we receive one-third of the income derived from the national grant, we have watched the experiments in this department, which the various schools have been making, with the deepest interest; believing, that the time would come, when the best solution would be reached, and trusting that when it was reached we should be in a condition to take advantage of the experience. In the meantime the steam laboratory is all we have been able to furnish of a practical character to our students in mechanical engineering, beyond what could be gained by a good locality for manufacturing, and the particular kindness of the directors.

We went to Philadelphia, therefore, earnestly seeking for light, in this as well as in all other directions, and this special report is now made to ask your attention to a fundamental, and, as I think, complete solution of this most important problem of practical mechanism for engineers. The question is simply this — Can a system of shop-work instruction be devised of sufficient range and quality, which will not consume more time than ought to be spared from the indispensable studies?

This question has been answered triumphantly in the affirmative, and the answer comes from Russia. It gives me the greatest pleasure to call your attention to the exhibit made by the Imperial Technical Schools of St. Petersburg and Moscow, consisting entirely of collections of tools, and samples of shop-work by students, illustrating the system which has made these magnificent results possible.

In all constructions a certain limited number of typical forms are found, these forms being more or less modified, to adapt them to special constructions. These forms will also fall into groups, each to be worked out in a certain way and with special tools. If, then, the student can be taught to work out these forms, each in

the best way, and with the tools best adapted to the work, he will be far advanced in the skill which will make him available and useful in construction. The ideas involved in the system are, first, to entirely separate the *instruction* shops from the *construction* shops; second, to do each kind of work in its own shop; third, to equip each shop with as many places and sets of tools, and thus accommodate as many pupils, as a teacher can instruct at the same time; and fourth, to graduate the samples to be made in each shop according to some scale, that of difficulty being probably the best in practice.

It will be seen, then, that the problem thus far is simply one of systematic instruction, given by an expert in each shop, and having the same end in view as instruction in any other subject or department. The aim is to give sufficient skill in each specialty in the shortest possible time, and to give the instruction to as many at the same time as the teacher can well instruct, thus securing the greatest economy of time, and therefore money, to both teacher and pupil. After the student has finished his course in the several instruction shops, he may then be transferred to a construction shop, which may still be used simply for instruction, as in the St. Petersburg school, no orders being taken, and all constructions being made simply to give variety to the instruction; the machines and tools made being sold at the end of the year if wanted.

Or he may be transferred to a construction shop, which takes orders and depends largely upon the work of the pupils, as at the Moscow school, the construction shops being in each case owned and controlled by the school.

With this preliminary exposition, I propose now to ask your attention to details, mainly in connection with the statements which these schools make in explanation of their exhibits at Philadelphia.

And first, the statement of the St. Petersburg school:

"The Practical Technological Institute of St. Petersburg is one of the highest technical schools now existing in Russia, and has capacity for five hundred students. It is divided into two departments; mechanical and chemical.

The Mechanical Department prepares technical men for the

management of mechanical workshops, and of the rolling stock on railroads. Owing to this the Mechanical Department is divided into two special sections; one of them graduates engineers for the workshops, and the other for the railroads.

Before entering the Institute as student the young man must be graduated in one of the middle schools (gymnasiums), and must undergo a competitive examination.

The whole course of instruction in each department of the Institute is arranged for five years, and is divided into five yearly courses.

In the Mechanical Department the course of instruction includes: Mathematical analysis, natural philosophy, theoretical and practical mechanics, mechanical technology, the art of construction and the art of mechanical drawing. Besides this, a part of the time is employed by the students in manual labor in various workshops and mills belonging to the Institute.

During the full five years of the course of studies, six hundred and forty-eight hours are devoted to the manual labor in workshops. There the students, under the management of experienced masters, begin to exercise in the most simple works, gradually passing to more complicated, and at last finishing with construction and joining of all the parts of an engine.

The collection of practical works exhibited in the Machinery Hall by the Institute is composed of articles manufactured by the students during the year 1875, and represents the systematical course of practical studies adopted by the Institute.

The system introduced with this purpose is as follows: The practical studies are divided into three courses; for the first course each student is induced to work with a chisel and file upon the cast-iron, performing six consecutive tasks exhibited under the No. I. of the collection.

For the second course the students begin by working upon wrought-iron, fulfilling nineteen consecutive tasks represented under the No. II. of the collections. Thereafter they are removed to the fitting shops, where they are obliged to perform fifteen tasks, exhibited under the No. III. of the collection, occupying themselves with turning, cutting screw-threads and soldering.

The last course is intended for the construction and joining of different engines. The samples of machine tools built by the students of this course are exhibited under the No. IV. of the collection."

I am indebted to Dr. August Peters, Mechanical Engineer, and Director of the shops of this school, for the following details: The filer's shop, No. I, has about sixty places, each fitted with a vise, and the tools necessary to do the work of the course. The forging shop, No. II, is fitted with ten places, and the turning shop,

No. III, with sixteen places, the students working in these shops in alternating sections. The lathes are all run by the foot, and the only power used in any of these instruction shops is for the blast in the forging shop, which each student takes from the main pipe. Even here power could easily be dispensed with by attaching a hand blast to each forge. The shop work, which, it will be noticed, takes but six hundred and forty-eight hours for the four courses, is obligatory, and graduates are able to construct their own designs with their own hands.

The quality and variety of the work exhibited, and all done by the students during the year 1875, furnish the very highest evidence of the value and entire success of the system.

And second, I beg you to particularly notice the able and instructive presentation of this important subject by Victor Della-Voss, Director of the Imperial Technical School of Moscow, together with a brief preliminary statement of the general features of the school. I am indebted to Professors Aeschlimann and Petroff, the gentlemen in charge of this exhibit, for polite attentions.

"The Imperial Technical School of Moscow is a high class Special School, principally intended for the education of Mechanical Constructers, Mechanical Engineers and Technical Engineers.

The School consists of two divisions, general and special, each of which has a course of three years. The special division is divided into three branches: Mechanical Construction, Mechanical Engineering and Technological Engineering.

The three years' course of the general division embraces the following subjects: Religion, Free Hand and Linear Drawing, Descriptive Geometry, General Physics, Zoology, Botany, Mineralogy, Chemistry, Geodesy, Analytical Geometry, Higher Algebra, Differential and Integral Calculus, General Mechanics, Drawing of Machine-parts, the French and German Languages, *i. e.*, all Scientific subjects, the previous knowledge of which is required from the pupils of all the three following branches.

In the special department, the three years' course of the three branches contains the following subjects: Organic and Analytical Chemistry, Metallurgy, Practical Physics, Mechanical and Chemical Technology, Technics of Wood and Metals, Analytical Mechanics, Construction of Machines, Practical Mechanics, Railway Construction, Engineering and Constructive Art, Projecting and Estimating of Machines, Works and Mills, Industrial Statistics and Book-keeping.

Every one of the appointed sciences is taught fully, or in a condensed form, according as it is considered a fundamental or collateral subject of the given branch. The students of all the classes are occupied during a stated time in practical work in the laboratories and mechanical workshops.

The School has also a preparatory division, of three classes, with the same curriculum as the higher classes of commercial schools, and is intended for such pupils as, by any reason whatever, have not been enabled to pass through the full course of the commercial or of the classical schools.

Admission into the School as boarder or day scholar is obtained by competitive examination, in accordance with the ordained programme.

Pupils who have passed through the full school course of the Gymnasiums may be admitted without further examination to the lectures of the second general class of the School, but pupils of the last class of the Gymnasiums, who have not passed their final examination, are admitted only to the first general class of the School.

The pupils wear the appointed half-military uniform.

Pupils who have obtained in the school the appointed grades, receive acknowledged rights in the service of the government.

The School is maintained by funds from the following sources: percentage on funded capital,[1] fees of private boarders and foreign hearers, and profits received from the Mechanical Works.

The annual receipts of the School amount to 160,000 dollars.
" " expenses " " " " 140,000 "

The Technical School is under the immediate patronage of *Their Imperial Majesties.*

Auxiliaries to Instruction. The School possesses a special library, containing more than six thousand volumes of works on specialties, a cabinet of physics, two chemical laboratories, a cabinet of mechanical models, a cabinet of natural history, extensive mechanical works with separate smithy and foundry, and also school work-shops.

Almost the whole of the collections exhibited by the School at the exhibition at Philadelphia, are immediately connected with the school workshops, and we shall therefore endeavor to give a few details concerning the latter.

No one will deny that a close acquaintance with hand labor, and, in general, practical experience in mechanical works, are matters of the utmost importance to every engineer.[2] The drawings of an engineer thus trained will always be distinguished by solidity and that practical judgment, which is the result not only of the study of scientific truths, but also of the acquirement of a

[1] The School capital amounts to about 2,030,000 dollars.
[2] We speak here of Mechanical Engineers and Constructers.

certain familiarity in their application to practice. That the knowledge of hand labor is of extreme importance to a young man devoting himself to technical activity, and that it is considered an absolute necessity to him, we are convinced by the circumstance that the greater number of the polytechnical schools of western Europe demand from the students who enter them either a previous stay, of a certain duration, at some works of industry, or issue to them a diploma, attesting their accomplishment of the course, after they are in position to show that they have been occupied practically for a definite period at some such works on their leaving the school.

If we contemplate the matter itself more profoundly, and acquaint ourselves more closely with the circumstances of the practician at private works and mills, we must, disregarding exceptional cases, since it is not those which form the rule, arrive at the sad conclusion that a young man, desiring to acquire practical experience in a short time, and without the aid of an experienced guide, loses, at private works, nine-tenths of his whole time entirely unprofitably. As we are at present addressing persons well acquainted with this matter, we do not consider it necessary to bring forward arguments in support of our statement. The practical information, acquired in works by a young man before entering a polytechnical school, is very inconsiderable, and therefore does not possess the desired significance.

Such information is, on account of its defectiveness, of little assistance in promoting the study at school of Practical Mechanics, the construction of machines or the drawing up of plans and estimates for mills and works.

A young man on leaving a polytechnical school should endeavor to carry on his practical education; should fix upon some mill or works in which, being, in the majority of cases, of course, left to his own initiative, he may find place and opportunity for his further self-education.

At this moment, so critical in the career of the youthful engineer, the insufficiency of material resources is the cause that the majority take service, at a very low rate of remuneration, as draughtsmen in the drawing office of mechanical works, or in the drawing offices of railway companies; others more fortunate enter works in the quality of artizans; but even they are hardly to be envied, simply from the fact that in the majority of cases the specialty of the first works, which they happen to enter, becomes their own specialty through life. An experienced observer will find no difficulty in perceiving all the inconveniences to a technical education, which arise as the result of such an order of things. Let us explain this by examples. A young man, having received thorough scientific preparation in a polytechnical school, has entered as artizan practician some extensive joiner works, and in a year or two begins to serve in the capacity of a workman, receiv-

ing pay from the works. If, from any circumstance whatever, he becomes deprived of his place, he finds it necessary to seek another in a similar joiner works, or else to enter again as practician in another specialty, for instance, a locomotive, boiler or other works. The material resources of young men preclude, in the majority of cases, the possibility of their deciding on the latter alternative.

If the observant Directors of Polytechnical Schools should take upon themselves the work of following the industrial career of the contingent of their pupils, who on leaving school enter a drawing office, they would easily perceive that those young people experience extreme difficulty when they are once engaged there in leaving such an office, and in the majority of cases remain draughtsmen all their lives. In such offices a young man acquires but very inconsiderable technical iuformation, neither can they in any way serve him as practical schools for his further self-instruction. And we must here observe, also, that the more extensive the works, and consequently the drawing office attached, the fewer are the advantages offered to the young practician, since he has to do with an institution in which division of labor, forming an essential principle, will not admit of his becoming speedily acquainted with the general progress of work. We cannot but add that this principle having become latterly extensively applied in all large works and mills, though on the one hand bringing considerable material advantages to the proprietors, has, on the other, greatly influenced the depreciation of the level of technical knowledge among the workmen, by confining that knowledge within the limits of narrow specialization.

The technical education afforded to young men in almost all the Polytechnical Schools of Europe leaves, theoretically speaking, little to desire, but is exceedingly imperfect practically, and demands the particular attention of those persons who are entrusted with such instruction.

The peculiar circumstances, by which the young people who have finished the course of the Polytechnicums find themselves surrounded, do not admit before their entering upon an active life, of the acquirement of even a superficial general practical education, but place them in the necessity of devoting all their activity from the first day of their leaving school, and often their whole life, to a narrow specialty. The attention of the Directors of Polytechnical Schools has often been drawn to this, and attempts have frequently been made to familiarize young people at school with the practical work of mechanics, but all these endeavors have proved to be unattended with success from the following reasons:

1. The school workshops for the practical occupation of the students were constructed on a very miniature and inconsiderable scale.
2. The consequent want of room in these workshops did not admit of all the students being occupied at the same time, and therefore their attendance was not obligatory, while the majority of the professors and masters expressed their disapprobation of such employment.

3. There existed no systematical method of practical instruction in the workshops similar to that which had been applied to the practical teaching in the chemical laboratories.
4. The material resources assigned for the maintenance of the school workshops were very inadequate.
5. The time allowed for the full course of study in the Polytechnical Schools was insufficient to admit of the combination, in that course, of theoretical with practical instruction in technology.

Though there have appeared some literary articles against the introduction of practical instruction with workshops into the higher technical schools, yet it is our subjective opinion that those articles appeared only in defence of the existing order of things, and to justify a certain lukewarmness in introducing advantageous measures, but no demonstration of the results of trial were afforded among the arguments against such a mode of instruction, for the simple reason that excepting feeble attempts, no serious experiments have been made. Even those attempts themselves were made without any particular energy and due observativeness.

We do not here take into calculation some of the at present existing technical schools of France, which possess sufficiently extensive school workshops,[1] because those schools belong rather to the lower class technical institutions, and do not give to the world mechanical engineers and constructers, but only foremen (contremaîtres).

The slight acquaintance of learned technologists with practical work in mechanical workshops, entails the unfortunate consequence that in the greater number of even very extensive works the practical part remains in the hands of routined artizans who have received no scientific instruction, but who have attained their exceptional position by accustoming themselves during the course of many years to the most obsolete methods of practice in the mechanical art.

Seldom do the rays of science penetrate that unenlightened sphere of labor, and, meanwhile, it has so long demanded scientific guidance.

The Imperial Technical School of Moscow, the course of which, from the theoretical subjects taught therein, equals the course of many of the Polytechnical Schools of Western Europe, combines theoretical with practical education, and consequently is enabled to present real proofs of the possibility and advantageousness of such combination, since the trial of this combination has been made on an extensive scale, and during a considerable length of time.

Every thing that we have exhibited at the international exhibition relates exclusively to this, in our opinion, important question, and was exhibited in the desire of sharing with specialists in the

[1] These are the schools of Chalons, Aix and Angers.

work of technical education in the New World, all those results which have been attained by the School in the independent investigation of this special question.

For the practical education of young men in the two branches,— mechanical engineers and mechanical constructers[1]— the school possesses large mechanical works with hired workmen, accepting and carrying out orders from private individuals, and on a commercial footing, for the construction of steam engines, working engines, pumps, transmissions, agricultural machines, etc.[2]

The works consist of the following shops: Joiners' shop, Engineers' shop, Erectors' shop, Painters' shop, a large Forge with steam hammer and fan blast, iron foundry with furnace for 3000 kilogr. of metal, and brass foundry; the works have also a drawing-office and counting-house attached to them.

A steam engine of thirty horse-power is used for the working of the place, while the foundry with fan blast and coal pulverizing-mill are worked by an engine of ten horse-power.

The works are under the management of the head mechanical engineer (vacant) and his assistant, Platonoff, mechanical engineer.

The drawing-office is in the charge of Petroff, mechanical engineer. All the mentioned persons have passed through the course of our school.

These works being within the walls of the institution itself, and managed by well-instructed technologists, would be of important assistance in the instruction of young people, even if the young people took no active part in the practical working of them.

But in order that the pupils may derive the greatest possible advantage from such auxiliaries, the school possesses, apart from the mechanical works, and intended solely for the use of the pupils, school workshops: joiners' shop with turning lathe, pattern shop, metal turning, fitters' shop, smithy and moulding shop.

Every one of these shops is under the management of a technologist — specialist,[3] or of a skilled workman, and their duty is to instruct the pupils in the rudiments of mechanical labor.

Every young man becomes acquainted, by fulfilling the obligatory programme, with all the work of mechanical art, namely: turning, fitting, carpentering and forging, in the school workshops, and only then is admitted to the mechanical works.

We shall endeavor to speak further, on the system of teaching the arts in the mechanical workshops of the school.

Up to the present time throughout the world, the workmen at industrial works and mills are usually self-taught. Any one who

[1] Young men studying the technological engineering branch are admitted to the laboratories instead of the mechanical workshops.

[2] These works execute private orders to the sum of from 35,000 to 46,000 dollars annually.

[3] The wood turners' shop is in charge of Mr. Adelmann, the smithy — Mr. Bouroff, carpenters'— Mr. Michaeloff, metal turners'— Mr. Markoff, moulders'— Mr. Koumenius, and the fitters' shop—Mr. Sovetkin, mechanical engineer.

has himself been employed at works, and is familiar with the daily life of the workman in the different countries, must have perceived that the acquirement of knowledge and skill in any trade is to him a process much similar to the following: a boy of thirteen or fourteen years of age having entered a mechanical works to learn his trade, is put during the first few years, to work of an entirely unproductive kind, and which has not the slightest relation to technics. He is made to carry water, sweep the workshop, crush emery, grind colors, etc. Only after the lapse of a few years, and, probably, thanks to accidental circumstances, a chisel or a file is put into the hands of the youth, and he is set to perform the rudest and simplest kind of work.

Then, also, if he happen to have neither father nor brother among the workmen around him, he begins learning his trade without a guiding hand, and thus commences acquiring practical knowledge and skill in his trade by observing those about him in the workshop, and by his own thought and calculation, and impelled by the sole desire of attaining in as short a space of time as possible the position of a paid hand in the works. There can be no doubt that under such circumstances the acquirement of skill by the new generation of workmen takes place in an extremely irrational manner, and without any system; the amount of knowledge obtained depends upon accident, and the time thus employed is of disproportionate length. Besides this, there is yet another inconvenience, namely, that of specializing labor to too fractional a degree. The young workman, placed accidentally either to a drilling or planing machine, or a self-acting lathe, endeavors to remain as long as possible at his machine, encountering, it will be understood, no objection on the part of the heads of the workshops, since such specialization of labor redounds to the advantage of the proprietors, owing to the abundance of hands.

This order of things has the deplorable result, that notwithstanding the long continued stay of the young workmen at mechanical works, and which is sometimes prolonged through the major part of the years of their manhood, well-taught and skilled fitters are almost everywhere rarely to be met with. This will be confirmed by all those constructers who demand skilled labor for the erection of models, and of the more or less delicately constructed instruments, machines and apparatus.

During the past few years endeavors have been continually made to open schools for the instruction of the workmen at all works of any considerable extent. The subjects taught in these schools are free hand and linear drawing, arithmetic, and many others, in the supposition that practical knowledge of works will be acquired in the works themselves.

From this it is impossible to conclude otherwise than that society, while taking measures to civilize the working classes, gives, at the same time, no attention whatever to the manner in which the

young workmen acquire practical experience in their trades at the works; no endeavors have been made in that respect, and, meanwhile, as is our subjective opinion, the question is worthy of particular attention.

The conclusion, however, forces itself upon us that this question can hardly be entered into until the young well-taught technologists, leaving Polytechnical Schools, shall themselves possess rational experience in practical hand labor. In order that their education as specialists shall be full and ample, such knowledge is indispensable in the highest degree, though, until the present time, it has unfortunately presented a prominent deficiency in their instruction. Who will not admit that the knowledge of the manner of executing given work is a necessity to one who has to issue the project of such work?

Acting on the principle that mechanical engineers and mechanical constructers, whose future activity will be devoted preeminently to mechanical works, should have practical experience in the mechanical arts, the Imperial Technical School has employed every necessary measure for the solution of this difficulty in the best possible manner.

In 1868 the School council considered it indispensable, in order to secure the systematical teaching of elementary practical work, as well as for the more convenient supervision of the pupils while practically employed, to separate entirely the school workshops from the mechanical works in which the orders from private individuals are executed, admitting pupils to the latter only when they have perfectly acquired the principles of practical labor.

By the separation alone of the school workshops from the mechanical works, the principal aim was, however, far from being attained; it was found necessary to work out such a method of teaching the elementary principles of mechanical art as, firstly, should demand the least possible length of time for their acquirement; secondly, should increase the facility of the supervision of the gradationary employment of the pupils; thirdly, should impart to the study itself of practical work the character of a sound, systematical acquirement of knowledge, and fourthly, and lastly, as should facilitate the demonstration of the progress of every pupil at every stated time. Everybody is well aware that the successful study of any art whatsoever, free hand or linear drawing, music, singing, painting, etc., is only attainable when the first attempts at any of them are strictly subject to the laws of gradation and successiveness, when every student adheres to a definite method or school, surmounting, little by little, and by certain degrees, the difficulties to be encountered.

All those arts, which we have just named, possess a method of study which has been well worked out and defined, because, since they have long constituted a part of the education of the well-instructed classes of people, they could not but become subject to

scientific analysis, could not but become the objects of investigation, with a view of defining those conditions which might render the study of them as easy and regulated as possible.

This, however, cannot relate to those arts which have been hitherto pre-eminently followed by the common and imperfectly educated class of workpeople, but a knowledge of which appears at the present moment, to be of importance to the educated technologist.

These arts are: wood-turning, carpentering, metal-turning, fitting and forging. From what we have already said, it will not be difficult to arrive at the reason of the absence of a strictly systematical method for the study of them, nor why the active working out of such a method, without the aid of enlightened minds, may long remain deferred.

Meanwhile the necessity of such a method, more particularly for technical educational establishments, admits not of the slightest doubt, and the filling-up of this want promises evident advantages, not only in the matter of scientific technical education, but also with regard to the practical instruction of the work people, and consequently, the perfection of mechanical hand labor itself, which, from the introduction of specially adapted machinery is, year by year, perceptibly deteriorating.

If we except the attempts made in France in the year 1867 by the celebrated and learned mechanical engineer, A. Cler, to form a collection of models for the practical study of the principal methods of forging and welding iron and steel, as well as the chief parts of joiners' work, and this, with a purely demonstrative aim—no one, as far as we are aware, has hitherto been actively engaged in the working out of this question in its application to the study of hand labor in workshops. To the Imperial Technical School belongs the initiative in the introduction of a systematical method of teaching the arts of turning, carpentering, fitting and forging.

To the knowledge and experience in these specialties of the gentlemen entrusted with the management of the school workshops, and to their warm sympathy in the matter of practical education, we are indebted for the drawing-up of the programme of systematical instruction in the mechanical arts, its introduction in the year 1868 into the workshops, and also for the preparation of the necessary auxiliaries to study. In the year 1870, at the exhibition of manufactures at St. Petersbourg, the school exhibited its methods of teaching mechanical arts, and from that time they have been introduced into all the technical schools of Russia.

The auxiliaries of education employed in teaching mechanical arts were exhibited at the international exhibition of Vienna, and now at Philadelphia, in order that specialists in these matters might become acquainted with them.

The auxiliaries of education appointed for the teaching of any mechanical work whatever, for example—fitters' work, are classed

in three categories; to the first of these belong the collections of instruments employed in fitters' work, with which the beginner must make himself perfectly familiar before entering upon work, and afterwards to use these instruments during the execution of the work itself.

To this category relate all those collections of models indispensable to the teacher of fitters' work, for the purpose of demonstration: the collection of instruments most in use for measuring, full size; the collection of instruments, full size, for drilling metals; the collection of instruments, full size, for finishing, from the smithy to the fitting shop inclusive.[1]

Models of files, increased to 24 times the ordinary size, for the purpose of demonstrating the surface of the incision; the collection of models of instruments employed in cutting screws and nuts, increased six times ordinary size, for the study of the direction of the angles of incision; the collection of models of drills, increased six times, for the practical study of the cutting angles; and lastly, the collection of instruments and apparatus for teaching the tracing of yet unworked metal articles. We consider it our duty to draw the attention of specialists to this last collection, for the organization of which we are indebted to our skilful instructor of fitters' work, Mr. Sovetkin, mechanical engineer.

To the second category belong the collections of models appointed for the systematical and gradationary study of hand labor in the fitters' art. These collections have the same signification with regard to the work of fitting as is allowed to scales and exercises in instruction in music. They are so ordered that the beginner may be enabled to overcome by certain gradations the difficulties which present themselves before him. It will be sufficient to glance at the adjoined detailed list of objects contained in these collections, and to examine attentively every object exhibited, to be convinced, that if the pupil, under the guidance of the teacher, carefully fulfils the study of all the numbers embraced in the collections, or rather the educational programme of the art of fitting, he must inevitably, and in the most rational manner, render himself familiar with all the known practical hand labor of this art.

Hence we arrive at the conviction, without any difficulty, that with such a system of teaching art, the supervision of the teacher over the pupils, and his observation of their progress, become exceedingly easy. He need only remark that every number of the programme is executed satisfactorily by the pupil, and putting the following one before him, give the requisite explanations for the succeeding work.

In such a case, the fact of a great number of pupils being occu-

[1] This beautiful and ample collection could not be sent to the Exhibition in consequence of the limited space allotted to us.

pied at the same time will present no great disadvantage, nor will it increase the arduousness of his duty to any considerable degree. And further, it will be a matter of impossibility that a pupil who has been working during a few years in the workshop, should fail to be able to use the drill, or to trace a part to be worked, though he handle satisfactorily the chisel or the file.

To the third category belongs the collection of such articles, or parts of machines, as in the execution of which all the practical hand labor of the fitter's art is successively repeated, having been acquired during the studies of the previous course.

What we have said in relation to the manner of study of the work of fitting, must be accepted also with regard to the other branches of labor, namely, wood-turning, carpentering, smithy and foundry work. We exceedingly regretted that the limited space allotted to us in the exhibition did not admit of our exhibiting all those collections of auxiliaries to instruction which the School has produced.

In conclusion, we consider it our duty to observe that eight years have already elapsed since the programmes of instruction in the mechanical arts were introduced into the workshops of the School, and they have been found to attain in the most brilliant manner the aim proposed in their introduction.

VICTOR DELLA-VOSS,

Director of the School, and Ex-Professor of Practical Mechanics at the Agricultural and Forest-Academy Petrofsky-Rasoumofsky.

Next I include a condensed catalogue of the exhibit of this School, showing the collections of tools pertaining to each kind of work, and the number of samples which each student must make in each shop. Attention is particularly called to the admirable series, N, O, P, of enlarged models for the practical study of the construction of cutting instruments, in the "School Fitting Shop."

SCHOOL WORKSHOPS.

I. WOOD TURNERY.

MASTER F. ADELMANN.

A. Collection of tools (about 150) for turning wood.
B. Part I. Samples (13) for the successive learning of turning in wood.
Part II. Casting-mould models of details and Machines (30).

II. MODEL JOINERY.

MASTER A. M. MICHAELOFF.

C. Collection of tools (34) for joinery.
D. Collections of tools (46) for joinery. Second series.

E. Samples (25) for the successive learning of joinery and pattern making.
F. Collection of models (25) of usual wood-joinings.
G. Collection of patterns (18) for iron castings.

III. FORGING.

MASTER S. BOUROFF.

H. Collection (60) of forging tools.
I. Samples (79) for the successive learning of blacksmith's manipulations.

IV. METAL-TURNERY.

MASTER A. M. MARKOFF.

J. Collection of tools (55) for turning metal.
K. Collection of tools (75) for turning metal. Second series.
L. Samples (38) for the successive learning of turning metal.
M. Samples (21) for the successive learning of turning metal. Second series.

V. SCHOOL FITTING SHOP.

MODELS FOR THE PRACTICAL STUDY OF THE CONSTRUCTION OF CUTTING INSTRUMENTS.

MASTER D. K. SOVETKIN, MECHANICAL ENGINEER.

Taking into consideration the importance of a knowledge of the proper construction of instruments, and the difficulty which has to be overcome in explaining to a whole mass of pupils the minutest details in connection with the direction and the angles of the incisive portions of instruments, we, already in the year 1872 endeavored to construct wooden models, representing instruments on a considerably increased scale. Part of these models was exhibited by us at the Polytechnical Exhibition of Moscow, in the year 1872.

Models of instruments on an increased scale present the advantage of rendering it possible for the student to see clearly all the minutest details of the construction of the instrument. The direction of the cutting edges, and also the shape and direction of the level surfaces which form the working part of an instrument, should be studied in the most detailed manner, and how is this possible when these portions of an instrument are hardly to be seen by the unaided sight. Let us take for an example the cut of a smooth-file; is it possible to form a clear comprehension of the shape and direction of the teeth without the aid of the lens? Certainly not. If, then, we form the tooth of the file, increased to twenty-four times the ordinary size, all the surfaces around it will be presented as practically clearly, as will enable one not even engaged in the special study of the matter, to form a clear idea of the shape of the tooth of the file. At the present moment we

submit to the appreciation and judgment of the interested public models of the cutting parts of files, drills and instruments for the cutting of the screw, outside as well as inside.

The three following lists will serve as the basis of the entire range of the collections, which represent all the instruments employed in work.

N. Models of drills and countersinks increased six times the ordinary size.

1. Model of cutting edges of a drill (double cutting) for drill-bow.
2. Model of cutting edges of a drill (one cutting) for drill-bow.
3. Model of cutting edges of a drill for crank-brace.
4. Model of cutting edges of a center-bit with long point.
5. Model of cutting edges of a center-bit with short point.

Remark. In models No. 1–5, are clearly shown the shapes of the cutting edges, and also the angles of the working surfaces. From an examination of these drills it will be easily seen the work of such instruments cannot be called good by reason of the irregular direction of the working surfaces.

6. Model of cutting edges of a drill, which edges have the favorable angles for the work.
7. Model of cutting edges of an American spiral-drill, distinguished by stability and exact work.
8. Model of cutting edges of a drill for boring turning-joints.
9. Model of cutting edges of a drill for half-ball borings.
10. Model of cutting edges of a fashion drill.
11. Model of cutting edges of a cone-countersink for wrought-iron and cast-iron.
12. Model of cutting edges of a cone-countersink for brass.
13. Model of cutting edges of a hemisphere countersink.
14. Model of a drill-stock with the cutter, showing its cutting edges and fastening.

O. Cutting parts of files increased twenty-four times ordinary size.

1. Tin-file.
2. Rasp-cut for lead and soft allayage of metals.
3. Sample of the first-course of files for hard metals, in order to show the angles of the working surfaces and cutting edges.
4. Sample of the first course and the second course, in order to show the beginning of file-teeth.
5. Sample of the first course of a smooth-file, in order to show the angles and form of the working surfaces.
6. Sample of the second course for smooth-files.
7. Sample of the second course of a fine cut rasp, in order to show the proportions of teeth.
8. Sample of the second course of an armfile, in order to show the proportions of teeth.

Remark. The three last samples show clearly and practically the size of the teeth of the most used files.

P. Screw-cutting tools, increased six times ordinary size.

1. Model of a screw-tap with conical nucleus and thread.
2. Model of a screw-tap with cylindrical nucleus and conical thread.
3–6. Models of screw-taps for nuts having holes not going through (complete assortment).
7. Model of part of a screw-plate for cutting external screw-threads.
8. Models of screw-dies with obtuse cutting angles.
9. Models of screw-dies with right cutting angles.
10. Models of Whitworth's screw-dies.

Q. Collection of instruments (about 90) employed in making apertures of various shapes.

R. Collection of instruments of measurement (43) used in studying the art of fitting.

S. Course I. Time for study, 240 hours. Samples (28) for the successive learning of the filer's trade.

T. Course II. Time for study, 240 hours. Samples (23) for the successive learning of the filer's trade.

U. Course III. Time for study, 240 hours. Samples (24) for the successive learning of the filer's trade.

Remark. The method of systematically teaching the art of fitting was first worked out in the Imperial Technical School of Moscow in the year 1868, and after eight years' trial has proved of immense advantage to the School itself, as well as to those of the Russian technical schools which borrowed that method of the Moscow Technical School at the time of the Petersburg exhibition of the year 1870.

In attestation of the utility of the proposed systematical method of teaching, we may observe that immediately after its being presented to the public in the year 1870, the Imperial Technical School received orders for similar collections from technical schools in Moscow, Petersburg and Odessa.

V. A bench, instruments and apparatus (13) for marking and lining machine-parts to be worked.

W. Collection of models (11) for the demonstrative instruction in the marking and lining; the red lines represent the geometrical axis, and the lines according to which the work must be carried out.

In all that precedes, I have endeavored to set forth, as clearly as I could, the general considerations upon which this system of shop instruction is based; to show that the solution of the problem has been approached from the instruction side, and not from the construction side, and in this consists its fundamental and thoroughly practical character, as part of a system of education. The system presupposes the student's ignorance, and begins at the foundation, both in theory and practice. Every step well taken from such a beginning is a clear gain, and the successive steps have only to be taken to arrive at the goal of success. The com-

plete demonstration, however, is seen in the results exhibited at Philadelphia — results which no mixed, or less systematic system could possibly produce.

Another value of the system is, that it is equally well adapted to the wants of each class, or grade, of students. If one wishes to be a mechanical engineer, and finds that he has the ability to master the highest theoretical questions involved, the amount of shop work will be graded to meet his needs; if, on the other hand, the student looks forward to the rank of a first class machinist, he will need more mechanical dexterity, and will therefore work out a larger number of examples, and be required to do less in the higher mathematical and theoretical studies.

It is also an exceedingly important feature of this system that the instruction shops are the least expensive to equip and maintain — and further, it is not necessary for the highest success of this instruction, that construction shops should also be immediately connected with the school, either as at St. Petersburg or at Moscow. The young engineer, or machinist, after graduating in such a course, will find no difficulty in completing his practical education in great manufacturing works, and probably under circumstances quite agreeable to those who have already spent all they could borrow to complete their chosen course of study. Further, the system applies equally to all industrial arts needing manual skill.

Even, now, the Department of Industrial Design, established in this Institute four years ago by the Trustee of the Lowell Institute, and which has in this short time attained such marked success, needs that its course of study should be materially widened and enlarged before it can take rank as a school of technical education in the textile manufactures. Practical instruction in weaving, the study of the textile materials used in the various fabrics, with the operatious of spinning, scouring, fulling and finishing, should be added. Systematic school instruction in such specialties has so long existed abroad as to have become a recognized element in the quality of their textile manufactures. If Massachusetts expects to keep the lead in the quality of her industrial work, it must be done by the establishment of technical schools for teaching the manipulations, with such other special knowledge as each

particular art requires. In each case the details must be worked out simply as an educational problem, and the instruction put in charge of an expert specialist, who understands theoretically and practically the particular manipulation. With the same skill, energy and perseverance as are needed to command success in the teaching of any subjeet, we shall not fail of corresponding success in the teaching of practical industrial art. With the ability to make will come the desire to create, to those who have the capacity to rise into the higher realms of their chosen art.

In the light of the experience which Russia brings us, not only in the form of a proposed system, but proved by several years of experience in more than a single school, it seems to me that the duty of the Institute is plain. We should, without delay, complete our course in Mechanical Engineering by adding a series of instruction shops, which I earnestly recommend. The whole matter turns upon getting the proper rooms. It is already clear that there are no other difficulties which can not readily be surmounted. With such shops once established, we shall also be prepared to offer instruction to those who wish to become constructers, rather than engineers, and especially to the large class of pupils to whom such a systematic training, properly supplemented with other studies, would prove a valuable foundation for further study, or for business. For these classes of students I propose the following outline of

A TWO YEARS' COURSE IN PRACTICAL MECHANISM.

To be admitted to this course the applicant must be at least fifteen years of age, and must pass a satisfactory examination in the following subjects: — Arithmetic, Geography, English Grammar, English and American History, and Algebra through simple equations.

FIRST YEAR.

			No. of Exercises	*Hours per Week*
1	Shop Instruction		120	12
2	Algebra	1st half	45	3
	Plane Geometry.	2d half	45	3
3	Rhetoric and Composition		90	3
4	Free Hand Drawing		90	3

SECOND YEAR.

			No. of Exercises	Hours per Week
1	Shop Instruction		120	12
2	Algebra finished	1st half	45	3
	Solid Geometry	2d half	45	3
3	English Literature		60	2
4	French		90	3
5	Mechanical Drawing		90	6

With the sets of samples of shop-work which will come to us at the close of the exhibition at Philadelphia, and the averages of the times needed to make each, taken from the shop records, and other information kindly promised by Dr. Peters, we shall be able to start with reliable data upon which to build.

JOHN D. RUNKLE, *President.*

Mass. Institute of Technology,
Boston, July 19, 1876.