that is in use, and it is required to locate the cusps of a tooth on the pitch line OB from the centre A .

From the given centre draw an arc Cc internally tangent to the line of action at C , and the first cusp will be normal at c . From the same centre draw an arc $C'c'$ externally tangent to the line of action at C' , and the second cusp will be tangent to it at c' .

When constructing a tooth on this pitch line, the flank must end at the first cusp c . Furthermore, the curve of the face of any tooth that is to run with the gear must end at the point K on the arc CK ; for, if it is extended further it will interfere with and cut off a part of the working flank of the gear tooth.

To determine the position of the centre of the smallest pitch line that will avoid the cusps altogether, find by trial the required centre A'' from which but one tangent arc can be drawn to the line of centres at C'' .

ON THE VALUE OF TECHNICAL TRAINING, AND THE TEACHING OF DRAWING AND HAND- WORK IN PUBLIC SCHOOLS.

BY EDWARD COMBES, C. E.

[*Companion of Most Distinguished Order of St. Michael and St. George, Officer of the Legion of Honor, and President of the Board of Technical Education of New South Wales, Australia.*]

It may be well to introduce this important and interesting paper to American readers by a few words concerning its author and the circumstances under which it was written.

Hon. Edward Combes is an engineer of ability and distinction, among the earliest who sought in the antipodes opportunity to wrest from nature her secrets and her treasures. Going to the Colony of New South Wales as a mining engineer, equipped not only with a technical and practical training as thorough as his native England could afford, but also with a wide and varied polite education, he was

thrown at once into those hardships and dangers, and that necessity of encountering emergencies and overcoming obstacles, which characterized early Australian days. His skill and force of character soon won for him the important position of Government Engineer of Mines; and as his clear judgment became more and more conspicuous in days of turmoil, he was elected member of the Colonial Parliament. He afterwards accepted the important portfolio of Minister of Public Works, at the time when of all others competence and reliability was demanded by reason of the imminence of war between England and Russia, which would mean ruin for the then defenseless city and harbor of Sydney. His name is thoroughly identified with the fortifications and the railway system of the Colony. In 1878 he was chosen as the fittest person to represent his government and country at the Universal Exposition in Paris, where he was made one of the Jury of Award. During that year and part of 1879, Mr. Combes—who received from the British and French governments, in recognition of his ability and services, decorations which he honored in accepting—travelled through the greater part of Europe collecting upon the subject of technical education information intended to shape the coming school system of New South Wales; and visiting this country extended his inquiries with a thoroughness which those who met him and those who have read his admirable and exhaustive report upon the subject* will remember. It was my good fortune to be in almost daily contact with Mr. Combes, during the year or more in which these inquiries were extended in Europe and America, and I take pleasure in testifying to the earnestness and thoroughness with which each system was examined in the most trifling details of its application, and through the widest results which it produced.

Adding to his many attainments that of being a color artist, whose productions have received medals wherever exhibited, and whose ability in this line was recognized by his election as President of the Society of Water-Color

* *Report on Technical Education.* Official Document, Legislative Assembly, New South Wales. Sydney, 1887.

Artists of New South Wales, Mr. Combes can view this question of technical education, and particularly the matter of drawing and handwork, from more sides than any other engineer of my acquaintance; and the eminently practical character of his private and public occupations precludes his entertaining any visionary views upon the subject. As artist and educated gentleman, as engineer having also large mining and manufacturing interests, as legislator and as Minister of the Crown, Mr. Combes has based his opinions upon thorough knowledge of every aspect of the case.

After examining the subject thoroughly, we must conclude with him that to permit any child to grow up with but one side of his nature developed, is a wrong done to him and to society at large. If we do not *put the whole boy to school*, we are lessening his earning powers, adaptability and capacity for happiness and usefulness. If, after knowing the facts in the case, we allow to remain dormant or become dwarfed, any faculty, which has been implanted in the young beings entrusted to us for development, we are unfaithful stewards, incompetent and criminally-negligent guardians, meriting punishment and reproach.

ROBERT GRIMSHAW.

No apology is needed for the subject of this paper. The education of the artisan and mechanic has occupied the attention of the greatest statesmen, as well as that of the most distinguished and eminent educationalists, throughout the whole of the civilized world, for a considerable number of years. Inquiries have been made by boards, commissions and committees appointed by nearly all the leading governments of Europe and America, as to the advisability of technical teaching, and in every case the conclusion arrived at has invariably been the same, viz: that its importance and utility could not be overrated and that it was the absolute duty of their respective governments to provide such instruction in the best possible manner. This has been carried out with greater or less good results; and my object is to bring before you, in as concise a manner as

practicable, the existing facilities, in actual operation, for imparting this class of instruction, and the general character of the primary education given in different countries with regard to its connection with the technical training necessary to afford the young such opportunities of acquiring that characteristic knowledge suited to the works and manufactures belonging to the particular district in which the school is situated.

While no real difference has existed among the advocates of technical teaching as to its general advisability, there have been a variety of opinions as to the manner or method of imparting it. One great question is with reference to apprenticeship schools. It is contended on the one hand that the old system of apprenticeship has completely broken down, and that consequently it behooves the state or the municipal government to teach the various trades in schools instituted for that special purpose. On the other hand it is stated that these trade schools are objectionable, on account of an expense not warranted by the results, and, moreover, that properly-equipped technical schools for every trade would practically be an impossibility. They also argue that such schools are not thoroughly effective, as improved methods and machinery are being daily discovered and applied, and consequently, that such schools could never keep pace with the factory, however perfectly the school might have been established in the first place. That the work accomplished would not be real, but of a very mediocre class, and that for want of association with real workmen, the school-taught artisan would be unable to commence as a skilled workman. There is much to be said on both sides, for while there can be no doubt as to the utility of apprenticeship schools for turning out scientific and highly-skilled workmen, eminently fitted for foremen, managers or proprietors of industrial works, the cost of training in these institutions is too great altogether, for the system to be applied to the masses. There can be no doubt that there is room for many modifications of the systems, and that more economical arrangements will be made in the future development of these establishments, which are numerous in Europe and con-

stantly increasing. They have proved their value over and over again in forming the most thoroughly trained artisans in most kinds of skilled labor, both in the practice of the art and in the knowledge of that science which underlies it. I may mention here that the success which has attended the industrial schools, established by law in France, Belgium, Germany and Switzerland, to give technical instruction to the masses, who have to live by the work of their brains as transmitted through the work of their hands, has been simply marvellous. It has been positively proved that the technical or practical work never injuriously affects the theoretical studies, but that, on the contrary, the manual work acts as a stimulus in the subjects of descriptive geometry and industrial drawing. This affords independent and direct testimony that the mental and physical powers are in direct accord, and can be simultaneously or concurrently educated with advantage to both.

But whatever may be the differences of opinion with reference to apprenticeship schools or manual training, there are none existing as regards the necessity of teaching drawing, which is the true and solid foundation of technical training. Ten years ago I advocated the simple principle that drawing should be taught in all the elementary schools. In my opinion a child should commence drawing, when learning his alphabet; to learn the name of a letter, and at the same time to imitate its shape from a model, enables the child to learn reading, writing and drawing, at one and the same time. The child learns far more quickly than he possibly could if he were taught separately, for the one helps the other; the eye and hand are brought into unison from the first, and once this is firmly established everything else comes easy.

The importance of drawing in industrial education cannot be overrated. It is the foundation of all the constructive arts. No industries can wholly dispense with it, and its exercise instructs the eye and hand to travel together. It is an essential aid to every class of artisans, while it instructs and improves both mind and body in its imitation of nature. It has often been called a universal language common to

all people of every nation. It is therefore clear that it should be commenced at the very earliest period, so that from the beginning of the child's tuition his eye and hand should thoroughly understand each other.

I say that no difference of opinion exists as to the necessity of teaching drawing at the earliest age, and from my own knowledge, I can state that a child learning his letters in the way I have above stated, on the three subjects at the same time, certainly learns to read and write more quickly than he otherwise would. I am happy to say that drawing has been made a branch of primary education in almost every system of elementary public instruction, and is now considered as necessary to a child's education as writing. It is no longer optional, but a required study. Its adoption is no longer an experiment, but an undoubted established fact. This must be honestly considered and attended to by the teachers of state schools. Many public school-teachers have never had the opportunities that are now given in normal schools and training colleges, to acquire that freedom of hand so necessary to the skilful artist, therefore they should take every opportunity to improve themselves in free-hand drawing. I find, wherever I have been, that generally the teachers are making the most strenuous efforts to carry out the instructions of the school boards, and every year will make a marked difference. The teachers have themselves become convinced of the necessity of teaching drawing from the earliest age, and consequently energetically endeavor to qualify themselves to impart the required instruction. At the present moment a great movement is going forward. A school training is required that will give better results in the every-day work of life than have hitherto existed. Drawing must be taught, and this must be done honestly, and not in any half-souled manner. The teacher must throw himself, or herself, into the subject enthusiastically, and then proportionate progress will be made. It must never be forgotten that the practice of drawing renders the pupil more apt, and better able to receive any subsequent industrial training, no matter in what branch of applied art, or whatever may be the industrial occupation.

It should constantly be borne in mind that the shorter time required to reach the position of a skilled workman, is a direct money gain to the State, fully sufficient to compensate the cost of the education. Froebel says that "drawing, painting, and modelling must necessarily be considered as a part of the general comprehensive education and training of man. They must be early treated as actual objects of the earnest school, and not be exposed to an accidental, worthless and fruitless and wanton arbitrariness; neither with the view that each scholar becomes an artist in some kind of art, and far less with the view that each scholar will be an artist in all branches of art, both of which nullify themselves; but with the definite view that each man may be raised to the point of developing his nature faithfully, completely, and on all sides; that he can raise himself to the point of recognizing the all-sided and all-powerful nature of man; but especially, as has been already stated, that each man understands how to perceive and to value the results of genuine art."

In bringing up a child in the knowledge of what is good and true and beautiful, we find that the study of drawing has immense advantages directly valuable as educational influences, and where the greatest attention has been paid to this principle, there also we find the greatest practical skill. The educating power possessed by elementary drawing is not doubted, and the great accuracy which drawing requires affords the best possible practice to the eye and hand, while of great value in training the mind to be observant, judicious and active. Imagination precedes reasoning, therefore the imagination should be cultured in primary education in such a way as to occupy a prominent place. We know that nothing is more attractive to the imagination than the beautiful. The sense of the beautiful is called *taste*, and should be accorded a first place in every system of instruction, more especially in primary instruction, and in the teaching of poetry and art; for, if education in the first place proceeds by images and realities, we should make use of them, by making them the vehicles of teaching the sublime and the beautiful.

It has been well said that beauty is another word for education, and the connection of culture in the beautiful, with culture in morals, is fully apparent. In the recognition and the feeling, the loving and doing of the beautiful, coarseness and vulgarity, and tendencies towards debasing and sensual enjoyments find a countervailing power. The virtues especially developed by the study of drawing are persevering industry, love of unobtrusive right action, order, decency and purity. Goethe says: "The importance of instruction in drawing as a part of education will best appear when we consider that by means of that acquirement we gain an increase of beautiful and noble pleasures derived from the external world. The whole realm of form and color opens to man; he acquires a new mental organ; he receives the most delightful ideas and learns to recognize, to respect, to love and to enjoy the beauties of nature. Nothing gives the same amount of true happiness as art. Why, therefore, should not the masses be taught to obtain the salutary influence which it gives to those who have cultured tastes and a love for the beautiful, and who can appreciate to the utmost, by sight and hearing, correct proportions and divine harmonies." The man who has during a certain number of hours of the day to labor to gain his livelihood would surely gain the greatest consolation and solace in being able to see and understand the beauties of nature, and endeavor, by his own hand, to reproduce what he sees in clay or in colors, or simply in black and white by his pencil. Impressions that we obtain by our sense of sight imprint themselves upon the brain, and where preconceived ideas are wrong, they are instantly changed for our benefit by the correct judgment of the eye. It is, therefore, universally admitted that drawing should occupy a most important position in primary instruction, and that, when taught as it should be, it not only gives the facility in a greater or less degree to represent the various forms which occur in almost all trades and professions, besides being of inestimable value in the work of ordinary life, but it gives to all that correctness of eye and taste without which the true sense of the beautiful can never be thoroughly understood. In archi-

ture, as in sculpture and painting, drawing is at once the instrument and the language. "To know how to draw," says Michael Angelo, "is to have the compass in the eye." The geometrician wants the compass in the hand, but the designer and painter want it in the eye. In the first place, mental calculation is required, while in the second there is an immediate intuition in a single glance. It is usual to speak of different systems of art education as the French, South Kensington, German or American methods, whereas in none of these countries is there any hard and fast, or even any comprehensive system of giving instruction in art for the public schools. As a matter of fact there is no absolutely national system of art education. When any of these so-called systems are taught, they are found to be the method of some talented teacher who personally gives instruction and advice to each individual pupil. It will be impossible here to describe the various plans adopted by different teachers, but I may mention that the one great common difficulty is in qualifying the regular school-teacher to impart art instruction, and the only practical way out of the difficulty is to encourage teachers to attend training schools, whose classes shall be open to teachers during the ordinary vacations. I am aware that this has been partially done here, as well as in many localities in Europe, with excellent results. It stands to reason that once the ordinary school-teacher, who has the confidence of his pupils, is capable of cultivating a perception and love of the beautiful in their minds by means of drawing, half the work will be accomplished. To learn to draw will be no longer an arduous task, but a pleasurable recreation in which the children will delight.

In Germany the teaching of drawing has undergone considerable change within the last few years, chiefly owing to the admirable teaching of Mr. Jessen. His success became most remarkable. Mr. Jessen was a civil engineer of Hamburg, where he established, at his own expense, a special school wherein to experiment with a method he had conceived for teaching drawing. His first trials were so extraordinarily successful that the municipal authorities of

Hamburg took the school into their own hands and voted for its maintenance £3,500 (\$17,500) annually. This went on until 1875, when, on account of the ever-increasing number of the pupils, the municipality erected a new school, to which a museum was attached, costing £150,000 (\$750,000). and at the present time there are over 2,000 pupils receiving instruction. Mr. Jessen has been appointed the art director of all the municipal schools, so that his method of teaching might be generally adopted.

This method appears to consist less in the innovation of any new scientific means of teaching the principles of drawing, than in giving the pupil, individually, that particular and special instruction which the necessity of his trade or profession requires. The time of study is not fixed, and the pupils stay at school three, four or five years, according to their aptitude in acquiring the necessary instruction. Often the very intelligent ones obtain proficiency in two years. All the courses take place in the evening. The first half of the first year is exclusively consecrated to the study of the primary elements of drawing, such as are generally taught in all the schools; but drawing from the flat is absolutely forbidden. Every lesson is drawn from an object. In the second half of the year professional drawing is commenced, and as soon as the pupil really knows how to draw, his work is chiefly confined to models which apply to his particular profession. In the following years the professional work and general artistic work are about equally divided, and one day in the week the work is exclusively professional, under the direction of a working foreman. This class is often held in private workshops, to teach the application of the general principles learnt at school. Private workshops had to be used, as, at the time of my visit, the government had not organized any manual professional schools. The great singularity of Mr. Jessen's method is that the pupils do not receive their instruction in class, but that each one, individually, receives a personal intimate instruction, varied in accordance with his temperament and aptitudes. The professor is always in attendance in the school, where he is continually engaged inspecting the work of the pupils,

reasoning with them and giving them judicious counsel; in short, he follows step by step the work of each student placed under his direction.

It is this individual instruction that causes the great success of Mr. Jessen's method. It enables the teacher to take into particular consideration the capacity of each particular pupil. This is a most weighty circumstance, because, in drawing solid objects, the clearness and liveliness of the perceptive powers, the accuracy of the eye, and dexterity of hand must be brought out. These qualities are very important, and are found to differ exceedingly in different individuals. By *individual* treatment, those in every way naturally gifted need not be held back, while the weakest need not be dragged along in order that the medium, forming the majority, should not suffer.

The question as to the best method of giving a technical education to the youth of a country, is the great problem of the age. Upon its proper solution the prosperity of a country as regards its agricultural, industrial and commercial relations may depend. It concerns the working population, the masses of the people, over whom it is the duty of the government to watch with an ever-increasing solicitude. It is exactly this class of instruction which enables the future man or woman to earn a living, and by producing a good class of workmen to place the country in the best industrial position. The great desire of all nations is to produce work by which their respective populations may live, and this desire extends itself year by year in direct proportion to the relative increase of population. It is not only a social but a political question of the highest importance. To place the people of any country in a position to successfully compete with the rest of the world, is the object of all who desire their country's good. The imperative necessity of comparatively placing the people in this position is self-evident, and no one dares to question its practical utility. The matter to be considered is, how to do this in the most practical and effective manner.

The old system of making workmen was by the process of apprenticeship. This was the only road to learn a trade.

The apprentice paid a fee for instruction and received his board and lodging as an equivalent for his work. He was of the family of his master, his friend, and often became his son-in-law. There was every inducement for a master to teach his apprentice, accordingly apprentices were carefully instructed, and there existed a sufficiency of good artificers in proportion to the demand for their work. Now, however, this is altogether changed. The invention of machinery and special tools has destroyed the old workshop and diminished small factories, and the industrial system of the country has been revolutionized and reconstructed. This reconstruction has its good as well as its bad side. Manufactured articles of all kinds are incredibly cheaper than they used to be, and there is for all who choose a greater chance to enter the class of skilled artisans. On the other hand, the mechanic is kept week after week and year after year at one particular branch of the trade, such is the necessary result of a division of labor. There can be no doubt that this monotonous employment and specialization of labor tends to the degradation of the workman and to a diminution of the art-value of his work. The manner, therefore, of educating young artisans daily becomes more important, and an opinion is steadily growing up that our elementary training, whether for rich or poor, is still exceedingly incomplete, and will never become fitted to the wants of the time until it has undergone some radical modifications, and I thoroughly believe that these will take the form of manual training.

If we divide the future occupations of the youth of all countries into agricultural pursuits, industrial production and manufactures, distribution and commerce, together with the learned professions, we find that the teaching is not in accordance with this division, but that in the provisions made by the public or state schools, it would seem that all our young men were to become parsons, clerks and lawyers. There is nothing industrial in the curriculum or anything really adapted to the manufacturing requirements of the country. It indicates that educationists have begun at the wrong end. That the culture of the masses should

precede their industry, whereas it has been universally conceded that the ornamental should wait upon the useful. It remains, therefore, to instruct the masses in such a manner that, while giving them their ordinary tuition in reading, writing and arithmetic, they may learn to use their hands as well as their heads.

The question as to the possibility of organizing workshops in primary schools has been often considered. The decision arrived at has been generally in favor of the principle, but that the practical teaching of different trades would be next to an impossibility. To carry out a system of manual training in primary schools, it is necessary to generalize and to teach that class of work which is common to all handicrafts, and useful to everyone whatever may be his social condition; work just sufficient to develop manual dexterity, and which will also serve for purposes of recreation. This is not at all theoretical. The system has been applied in hundreds of cases, and given results eminently satisfactory.

The work adopted as the most convenient is that which is the most simple in its character; the easiest class of carpentry and wood turning. With boys there seems to be an innate longing to use carpenter's tools, and this is quite sufficient in the first instance to set in motion the constructive faculties, and to develop manual dexterity. Besides, these elementary exercises do not require large workshops or expensive tools, but can be taught in the play sheds of ordinary primary schools. In France, handwork in schools is now made compulsory.

I must, however, find space for noticing what has been done of late in Sweden, more especially in the training of the ordinary school-teacher, both male and female, so that they may be qualified to impart the knowledge of manual work to their pupils. In the Swedish language this handwork is called *slöjd*, a word which has no exact equivalent in the English language.* It is an old national word, coming from an epoch when nothing but hand tools were used. It

* Perhaps our word "sleight" still bears about the same meaning. R.G.

does not mean any handicraft, but implies a general sense of dexterity and cleverness. Thus, speaking of a farm laborer as a *slöjdare* means, that while he is simply a laborer, he is a handy man and able to use and repair the common tools and implements in use on the farm.

This simple work was originally taught to children by their parents, for it was customary with the peasant to make and repair any furniture or tools required by the family. This was generally done during the long winter evenings. When factories sprung up, making cheap articles of iron and ware to replace those wooden utensils, the desire and the aptitude for making them at home were by degrees lessened and, indeed, almost altogether destroyed. The workman degenerated to such an extent that the government instituted an inquiry into the cause, when it was found that out of twenty-four districts only five retained anything like the habitude and custom of this cottage labor. The laborer was no longer a *slöjdare*, and his production having ceased, the country lost a considerable source of wealth. It was thereupon determined that this manual training should be taught in all the primary schools.

The great difficulty was the teacher. It was necessary to train them, and here a patriotic gentleman, named Abrahamson, came forward, and not only established a normal school for the purpose, but duly endowed it, placing it under the direction of his son-in-law, M. Solomon, who was also one of the first and most fervent propagators of manual work in primary schools. In conjunction with the founder, this gentleman has carried forward the grand work with the greatest enthusiasm, and their wise lessons cannot possibly be studied without appreciating the important results that have been achieved by the teaching of handwork in primary schools.

It has been directly and definitely proved that this manual teaching must not be confided to artisans without any knowledge of pedagogy, therefore it goes without saying that in future handwork should be taught in all normal schools, and no appointment of teacher made to any school, unless he or she be duly qualified to impart this knowledge.

When manual work is universally taught in all primary schools, how much more efficient will become the professional and apprenticeship schools. The pupils having already gained that dexterity so requisite to all handicrafts. Moreover, the *habile* workman will be made in less time. He will be as clever and experienced at 18 years of age as otherwise he would have been at 21; thus three years will have been saved, and allowing a man able to work at his trade thirty years, there will be an increase of one-third in the producing power of the state, which, in a money value, would more than compensate the government for any sum it might expend in the complete organization and perfection of a thorough system of technical training.

The training now instituted in America, Belgium, England, France, Germany, Holland, Russia, Switzerland and many other countries is chiefly of a secondary character, the apprenticeship and professional schools are exceedingly numerous and constantly increasing. Time will not permit any detailed description of these schools, of which, perhaps, the *Ecole Diderot*, of the Boulevard la Villette, in Paris, is the best typical form, and young men leaving it readily obtain wages of from four to seven francs a day.

The opportunities and facilities for the acquisition of technical knowledge have been far greater in France than in any other part of the civilized world. In France, every instruction can be easily obtained. From the National School of the Fine Arts to the rudimentary class at the primary school, all is free, and throughout the whole of the country there are departmental schools, both in the day-time and during the evening, giving instruction gratuitously in every branch of art and design, and, as I have mentioned before, manual training is compulsory. This explains at once the reason that France exports millions, nay, hundreds of millions, of value in commodities, of which the chief value lies in the labor consumed in making the article, and every nation contributes to her prosperity in purchasing these commodities. The immense sums spent by the French government in providing the technical instruction for the production of workmen capable of this class of work,

are amply compensated by the wealth obtained through the contributions of capital by the entire civilized world.

With the progress and development of a nation, there ever follows a fiercer and fiercer competition in matters pertaining to labor. It therefore follows that for any nation to hold its own, the highest technical skill will be necessary. To obtain this skill the rising generation must be instructed, not only in the ordinary subjects of education, but also in the use of simple tools, so that manual dexterity may be obtained at the earliest possible period. The education that will compass this must necessarily bring about another desideratum. Children who have been taught the use of tools will not in after life look down upon those who labor with their hands. They will have been taught through the equality that exists in the school and as bench-mates in the work shop, that all labor is honorable, and that good fellowship should always exist between them as fellowmen, a feeling which cannot but conduce to the general diffusion of happiness, and consequently to the good of the commonwealth.

HARBOR BAR IMPROVEMENTS.

BY L. D'AURIA.

In an article published in the FRANKLIN INSTITUTE JOURNAL for July, 1889, under the above head, Prof. L. M. Haupt, C.E., shows in a very brilliant manner the momentous importance of removing bars which are formed by the forces of nature at the entrances of harbors, a fact, which has always been recognized by commercial nations, but believed by Professor Haupt to be disregarded by the Government of the United States, because this Government has not yet adopted his plan for removing such bars.

The professor wants the abolition of parallel or nearly parallel jetties as means to improve harbor entrances, and he quotes the highest English authorities on the subject. These authorities seem to discourage such jetties, but, as yet, do not feel competent to suggest new means; and it is