MATHEMATICAL ASSOCIATION

supporting mathematics in education

Laboratory Work in Connection with Mathematics

Author(s): R. C. Fawdry
Source: *The Mathematical Gazette*, Vol. 8, No. 116 (Mar., 1915), pp. 36-39
Published by: The Mathematical Association
Stable URL: http://www.jstor.org/stable/3604441
Accessed: 21-06-2016 01:53 UTC

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at
http://about.jstor.org/terms

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

The Mathematical Association is collaborating with JSTOR to digitize, preserve and extend access to *The Mathematical Gazette*

This content downloaded from 104.239.165.217 on Tue, 21 Jun 2016 01:53:47 UTC
All use subject to http://about.jstor.org/terms

V. Properties of Polynomials—differentiation and integration.

VI. Easy Series.

VII. Complex Numbers.

VIII. Study of Polynomials by means of the Argand Diagram.

IX. Study of $\frac{a_0z^m+a_1z^{m-1}+\ldots+a_m}{b_0z^n+b_1z^{n-1}+\ldots+b_n}$ – roots, poles, expansions at points, and residues. Much numerical work and generalisation of numerical properties that are always turning up. (This foreshadows practically the whole theory of Algebraic Functions, and opens up a vast field.)

X. Differential and Integration of Power-Series on the Argand Diagram.

XI. Only such Limit and Test-Theorems as are directly required by the above simple course. Nothing worse than the direct comparison with the Geometrical Series should be involved.

WILLIAM P. MILNE.

The President then requested Mr. R. C. Fawdry to read his Paper on:

LABORATORY WORK IN CONNECTION WITH MATHEMATICS.

ONE of the papers read last year at the Annual Meeting of this Association was on the subject of Practical Mathematics, but much of the value of the paper was lost as time did not permit of any discussion. To-day I propose to make my remarks very brief, as my chief object is to ascertain what steps are being taken in schools of various types, to bring the subject of Practical Mathematics into the School Course. I trust, therefore, that there will be an expression of opinion from as many members as possible.

In order to avoid any misunderstanding, I have entitled my paper "Laboratory Work in connection with Mathematics." This indeed is what I understand by Practical Mathematics. It will be obvious that such a meaning is widely different from that adopted by Professor Steggall in the remarks he made last year.

Numerical evaluation of algebraical expressions, accurate constructions of geometrical problems, plotting of curves, graphical solutions, use of logarithms in computation, in fact the bulk of the methods which have been adopted in the class teaching of Mathematics largely as the result of the efforts of the Mathematical Association—these to me do not mean Practical Mathematics. Such operations can be conducted in a class-room without the use of further apparatus than a box of instruments, some squared paper, and a table of logarithms.

Those who are familiar with the examinations conducted by the Civil Service Commission will be aware that the examination in Mathematics includes a practical test, conducted according to a prescribed syllabus, and it is in great measure due to the demands of these examinations that the attention of teachers has been drawn to the advisability of including practical work in the Mathematical Course.

Practical Mathematics according to this view requires something in the nature of a Laboratory. Broadly speaking, it is the application of Mathematical processes to data which have been obtained by the pupil as the results of experiments he has performed.

One obvious result of such practical work is the infusion of life into the dry bones of the technical procedure with which youthful mathematicians must be familiar before any great progress can be made in a Mathematical education.

This content downloaded from 104.239.165.217 on Tue, 21 Jun 2016 01:53:47 UTC
All use subject to http://about.jstor.org/terms

Professor Whitehead, in his little book *An Introduction to Mathematics,* states:

"The study of Mathematics is apt to commence in disappointment The important applications of the science, the theoretical interest of its ideas and the logical rigour of its methods, all generate the expectation of a speedy introduction to processes of interest. We are told that by its aid the stars are weighed and the billions of molecules in a drop of water are counted. Yet, like the ghost of Hamlet's father, this great science eludes the efforts of our mental weapons to grasp it, and what we do see does not suggest the same excuse for illusiveness as sufficed for the ghost, that it is too noble for our gross methods.

"The reason for this failure of the science to live up to its reputation is that its fundamental ideas are not explained to the student, disentangled from the technical procedure which has been invented to facilitate their exact presentation in particular instances."

We are making some attempt to prevent the study of Mathematics from beginning in an atmosphere of discontent and disappointment. The memory of our school days has made us merciful. The early steps in Arithmetic which plunged us into endless long division sums, the horrors of $5\frac{1}{2}$ yds. and $30\frac{1}{4}$ sq. yds., the interminable G.C.M.'s which wound their sinuous course about our pages—these, it is true, have largely disappeared, but the necessity for acquiring facility in computation remains. The introduction of practical work is to make these operations deal with data which are real; in short, we wish to stimulate interest.

Instead of giving the pupil a list of corresponding values of x and y and asking him to draw a graph to show the relation between them, we provide him with a stop-watch and a pendulum, and tell him to find the relation between the length of the pendulum and the time of an oscillation.

Instead of being told that if 56 sq. cms. of cardboard weigh 4·3 grams, find how many sq. cms. will weigh 10·2 grams, he is told to find the area of an irregularly shaped piece of tinfoil by cutting it out in cardboard and weighing.

The weakness of the text-book question lies in the fact that the necessary data for solving the problems are selected *for* the pupil, and not only the data but generally the method as well, for the questions to be solved according to a given model are usually grouped together.

In the Laboratory, the essential parts of the data have to be selected, irrelevant information has to be rejected,—the boy must use discretion, and his education correspondingly gains. He also learns to use what knowledge he already possesses. It is a common experience that a boy who is familiar with the operations of the Calculus, completely fails to apply his knowledge to a practical question. He will find in his text-book a volume V expressed as a function of x, the depth—he will find $\frac{dV}{dx}$, and will probably explain what it means. Put him in a Laboratory with a bucket and tell him to measure the depth of water in it, for increments of 1 litre in volume—plot the results on a graph and find from the graph the area of the cross section at various depths, and he will come and ask you how to do it.

I propose to deal but briefly with the question of ways and means, as it is this point which I hope will be discussed by those of my hearers whose experience is greater than mine.

The ideal of course is to have a Mathematical Laboratory, or at any rate a room devoted to this particular work. If such accommodation is available the expense of equipment is small, since the apparatus is all the better for being simple and not elaborate. I shall be glad if

This content downloaded from 104.239.165.217 on Tue, 21 Jun 2016 01:53:47 UTC
All use subject to http://about.jstor.org/terms

those members who have such a Laboratory will tell us how they consider it may be used to the best advantage. Those who have no such accommodation must fall back on the Physical Laboratory, but this is not often available for the purpose at the hours when the mathematician wishes to use it. It is most desirable that the Laboratory work should be taken by the masters who teach the mathematical set, but it is not all mathematicians who can be trusted to be let loose in a Physical Laboratory.

The alternative is to assign a definite period each week for Laboratory work, but this method results in the practical work being to some extent independent of the work which is being done in the mathematical set. It is then necessary to arrange a course of Laboratory work, more or less elastic, to be carried out by each set.

Here I should like to state my disapproval of the use of certain books which are published for this purpose. They contain a series of experiments, each accompanied by directions to be followed and a tabulated scheme with blank spaces for the numerical results obtained.

To my mind such a proceeding destroys one of the most valuable parts of the training. The boy must be told how to carry out the experiment, but he must write his own account of what he has done. He must make his own table of results of observations. By so doing he will in time acquire the power of expressing himself concisely in intelligible English and in a scientific manner. My own method is to have the details of the separate experiments pasted on stout cards, which are handed to the boys. The account of the work is written in note books in pencil, and, when satisfactory both as to accuracy and intelligibility, is signed by the master before the boy proceeds to the next experiment. A list of boys and experiments is kept, on which a record is made of the experiments completed.

It may be useful if I give in conclusion a brief outline of suitable work.

Elementary Stage.—Calculations of areas and volumes (invaluable for driving home the importance of significant figures and the necessity of giving results to the degree of accuracy justified by the data).

Illustrations of proportion, such as finding the area of an irregular lamina; calculating the weight of wood required for making a corner shelf from a given board.

Finding the area of curved surface of a cone made of paper by calculating the area of the sector of the circle into which it is developed.

Drawing graphs, *e.g.* length of pendulum and time of swing; oscillation of spiral spring with various weights attached; bending of a lath for given weights.

It is important that the graph, when completed, should be *used* to find some result not included in the observations.

Principle of Archimedes if such work is not included in the Physics Course.

Second Stage.—Use and principle of verniers, slide calipers, screw-wire gauge.

Numerous *Statical experiments,* of which it may suffice to mention the calculation of the efficiency of machines and the introduction of problems in three dimensions.

Dynamical experiments with Fletcher's trolley. Space-time graphs, velocity-time graphs. Acceleration of a sphere rolling down a plane. Experiments with Atwood's machine.

Reaction of a jet of water on the bend of a pipe, as in Ashford's *Dynamics*, p. 185.

Dynamical experiments are of great value in clearing up ideas with regard to units. Nothing is more common in experimental work than the habit of taking $g=32$, when all observations are made in C.G.S units.

This content downloaded from 104.239.165.217 on Tue, 21 Jun 2016 01:53:47 UTC
All use subject to http://about.jstor.org/terms

More Advanced Stage.—Experiments involving the application of the Calculus.

Area of cross section of a vessel from observations of volume and depth.

Moments of Inertia. Oscillating lamina. Compound pendulum.

Kinetic energy of fly wheel.

Applications of coordinate geometry in three dimensions.

R. C. FAWDRY.

The President next called on Mr. A. Lodge for his Paper on :

AN ELEMENTARY METHOD OF FINDING CIRCLES OF CURVATURE AT POINTS, MULTIPLE OR OTHER, OF A PLANE CURVE WHOSE EQUATION IS GIVEN IN RECTANGULAR COORDINATES.

THE method of finding the centre of curvature to which I wish to draw attention is as follows :

If PT is the tangent at a point P of a curve, a circle which touches the curve at P will in general cut it at other points Q, ...

Now, if P be taken as origin, and a homogeneous equation be formed by means of the equations of the curve and a tangent circle, this equation will represent all the chords PQ, ... The circle of curvature will be distinguished by the fact that one of these chords must coincide with PT. That is the whole spirit of the method : there is no calculus, and the method is available for all who can transform an equation to a new point as origin and can appreciate the meaning of a homogeneous equation. In many cases, comprehension of what terms are small enough to be omitted will facilitate matters, but it is not essential, and indeed the method can be made to develop such comprehension.

Ex. 1. *To find the circle of curvature at* (0, 0) *of the curve*

$$(x+y)^2=a(x-y). \quad \text{.......(1)}$$

Let its equation be $$x^2+y^2=k(x-y). \quad \text{.......(2)}$$

Then the homogeneous equation is

$$k(x+y)^2=a(x^2+y^2), \quad \text{.......(3)}$$

and this will be satisfied by $x-y=0$ if

$$k=\tfrac{1}{2}a\,;$$

∴ the circle of curvature is

$$x^2+y^2=\frac{a}{2}(x-y), \quad \text{.......(4)}$$

and the centre of curvature is at $\left(\frac{a}{4},\ -\frac{a}{4}\right)$.

Moreover, if in (3) we put $k=\frac{1}{2}a$, it becomes

$$(x+y)^2=2(x^2+y^2),$$
$$i.e.\ (x-y)^2=0.$$

Hence in this case the contact is of the 3rd order, as *all* the chords coincide with the tangent.

Ex. 2. *Case where the tangent at the origin is one of the axes.*

In this case the method leads to a quicker result.

Thus the circle of curvature at (0, 0) of $y^2=4ax$ is

$$x^2+y^2=4ax,$$

This content downloaded from 104.239.165.217 on Tue, 21 Jun 2016 01:53:47 UTC
All use subject to http://about.jstor.org/terms