ADVANCED ARITHMETIC

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649159277

Advanced arithmetic by William W. Speer

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

www.triestepublishing.com

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"This law of organic progress is the law of all progress. Whether it be in the development of the earth, in the development of life upon its surface, in the development of society, of government, of manufactures, of commerce, of language, literature, science, art, this same evolution of the simple into the complex, through a process of continuous differentiation, holds throughout."

— HERBERT SPENCER.

BOSTON, U.S.A.

GINN & COMPANY, PUBLISHERS

The Athenæum Press

1899

PREFACE.

THE purpose of this book is to aid the teacher in making conditions favorable for the contact of the learner with mathematical realities. Since the simplest as well as the most complex relations become known only through mental activity in comparing, attention is given to an environment which shall continually induce this activity. The comparison of magnitudes includes all the other operations of arithmetic. This is apparent when we reflect that all advance in knowing is by progressive acts of analysis and synthesis. Whether we compare by means of the object or by means of its symbol, the mind should still be free to move from the vague to the definite through its own acts.

In the first book of this series it was said: "That quantity is a ratio between terms which are themselves relative is a truth which has often been pointed out, but which the work of the schools shows to be felt by few." In the minds of many bred upon the language of mathematics, the mode of expression has acquired an independence which excludes the reality. The presentation of relative magnitude as a subject of study in the elementary school has, however, met with gratifying response. Some authors, indeed, whose presentations are entirely foreign to the development of ideas of relative magnitude, have recently written urging

relations of magnitude as the objects of study; others have given the *word* "ratio" a prominent place in new editions. "A religious vocabulary without religious experiences" is of little value; a mathematical vocabulary without mathematical experiences is of no more value. The student cannot advance in any science if his attention is absorbed in the language. Non-mathematical work cannot generate mathematical ideas. Definitions of mathematics and of quantity avail little without the feeling and the intimate understanding which cause us to shape our work in accord with the illuminating idea.

The mode of dealing with the greatest common measure, percentage, longitude and time, square root, mensuration is in accord with underlying mathematical ideas. The pupil advances in the indirect establishment of relations of magnitude by living in practical contact with mathematical realities.[1]

Each subject has its own elementary ideas. The study of relative magnitude does not give a basis for inferences in history or biology, nor does attention to history give a basis for mathematics. The power to say, "The act is brave," or, "The building is fitly proportioned," begins in comparing through the senses, but the observing which leads to one of these judgments does not furnish a basis for the other. But all elementary work should be formative of a mental habit which may be fitly carried into all lines of effort.

[1] "One well-known principle underlying the acquisition of knowledge is that an idea cannot be fully grasped by the youthful mind unless it is presented under a concrete form. Whenever possible an abstract idea must be embodied in some visible representation. . . . Should it appear to any one that we thus detract from the generality of algebraic quantities, it is sufficient to reply that the system is the same which mathematicians use to assist their conceptions of advanced algebra, and without which they would never have been able to grasp the complicated relations of imaginary quantities."—SIMON NEWCOMB.

Things must be observed in various aspects if they are to be known, but to say that too much attention to mathematics or to particular things weakens is merely to make a specific application of a universal truth.[1] The presentation in this series is from the standpoint that any success is dangerous which lessens the susceptibility of the mind. The constant purpose is to promote growing power to act in new circumstances.

W. W. SPEER.

[1] "The intensity with which any form of exercise is carried on during the growing period leaves its trace, and the absence of it at the proper time is for the most part irremediable. We should hardly expect much appreciation of color in a person brought up in the dark, however good his natural endowments in this direction. Thus any lack of early experience may leave a spot permanently undeveloped in the central system."— PROF. H. H. DONALDSON.

Nor can we expect appreciation of mathematical relations if there is no opportunity for attending to them. If we leave the sense of proportion undeveloped, and leave the pupil unaware of the realities of mathematics in the elementary work, we can scarcely expect interest in relative magnitude at a later period. — AUTHOR.

INTRODUCTION.

Interdependence of the Powers. — At all stages education involves the whole personality. Continued impressibility is a condition of growing power to think and act. Attempts to substitute the analytic-synthetic acts of the adult for those of the child separate the child from realities of which he would easily possess himself if not interfered with. Through many facts we rise to laws which embrace them all and lead to other truths. So the higher mental life embraces the lower and further develops, not by disuse of the powers, but by increasingly effective use of them. Varied *self*-activity is the great characteristic which distinguishes higher from lower organisms.

Means and End. — Intelligent effort is the adaptation of means to end. Mathematics is a means of educating, just as botany and history are. From the mathematical side the purpose of the study is the discovery of the relative magnitude of things. What, then, should be the course of procedure? Manifestly the learner cannot respond to that by which he is not affected. Is there any way by which he can become affected by relations of magnitude except by his own activity[1] of sense and mind in regard to such relations?

[1] "Thus even when the relation is directly presented, *e.g.*, in the spatial relation of two simultaneously perceived objects, it is evident that attention must direct itself to this relation, and selectively bring it into mental prominence." — JAMES SULLY.