The Teaching of Arithmetic I: The Story of an experiment

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In the spring of 1929 the late Frank D. Boynton, superintendent of schools at Ithaca, New York, and president of the Department of Superintendence, sent to a number of his friends and brother superintendents an article on a modern public−school program. His thesis was that we are constantly being asked to add new subjects to the curriculum [safety instruction, health instruction, thrift instruction, and the like], but that no one ever suggests that we eliminate anything. His paper closed with a challenge which seemed to say, "I defy you to show me how we can cut out any of this material." One thinks, of course, of McAndrew's famous simile that the American elementary school curriculum is like the attic of the Jones' house. The Joneses moved into this house fifty years ago and have never thrown anything away.

I waited a month and then I wrote Boynton an eight−page letter, telling him what, in my opinion, could be eliminated from our present curriculum. I quote two paragraphs:

> In the first place, it seems to me that we waste much time in the elementary schools, wrestling with stuff that ought to be omitted or postponed until the children are in need of studying it. If I had my way, I would omit arithmetic from the first six grades. I would allow the children to practise making change with imitation money, if you wish, but outside of making change, where does an eleven−year−old child ever have to use arithmetic?
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> I feel that it is all nonsense to take eight years to get children thru the ordinary arithmetic assignment of the elementary schools. What possible needs has a ten−year−old child for a knowledge of long division? The whole subject of arithmetic could be postponed until the seventh year of school, and it could be mastered in two years' study by any normal child.

Having written the letter, I decided that if this was my real belief, then I was falling down on the job if I failed to put it into practise. At this time I had been superintendent in Manchester for five years, and I had already been greatly criticized because I had dropped practically all of the arithmetic out of the curriculum for the first two grades and the lower half of the third. In 1924 the enrollment in the first grade was 20 percent greater than the enrollment in the second, because, roughly, one−fifth of the children could not meet the arithmetic requirements for promotion into the second grade and so were forced to repeat the year. By 1929 the enrollment of the first grade was no greater than that of the third.

Meanwhile, I was distressed at the inability of the average child in our grades to use the English language. If the children had original ideas, they were very helpless about translating them into English which could be understood. I went into a certain eighth−grade room one day and was accompanied by a stenographer who took down, verbatim, the answers given me by the children. I was trying to get the children to tell me, in their own words, that if you have two fractions with the same numerator, the one with the smaller denominator is the larger. I quote typical answers.

- "The smaller number in fractions is always the largest."
- "If the numerators are both the same, and the denominators one is smaller than the one, the one that is the smaller is the larger."
- "If you had one thing and cut it into pieces the smaller piece will be the bigger. I mean the one you could cut the least pieces in would be the bigger pieces."
- "The denominator that is smallest is the largest."
- "If both numerators are the same number, the smaller denominator is the largest − the larger − of the two."
- "If you have two fractions and one fraction has the smallest number at the bottom. It is cut into pieces and one has the more pieces. If the two fractions are equal, the bottom number was smaller than what the other one in the other fraction. The smallest one has the largest number of pieces − would have the smallest number of pieces, but they would be larger than what the ones that were cut into more pieces."

The average layman will think that this must have been a group of half−wits, but I can assure you that it is typical of the attempts of fourteen−year−old children from any part of the country to put their ideas into English. The trouble was not with the children or with the teacher; it was with the curriculum. If the course of study required that the children master long division before leaving the fourth grade and fractions before finishing the fifth, then the teacher had to spend hours and hours on this work to the neglect of giving children practise in speaking the English language. I had tried the same experiment in schools in Indiana and in Wisconsin with exactly the same result as in New Hampshire.

In the fall of 1929 I made up my mind to try the experiment of abandoning all formal instruction in arithmetic below the seventh grade and concentrating on teaching the children to read, to reason, and to recite − my new Three R's. And by reciting I did not mean giving back, verbatim, the words of the teacher or of the textbook. I meant speaking the English language. I picked out five rooms − three third grades, one combining the third and fourth grades, and one fifth grade. I asked the teachers if they would be willing to try the experiment. They were young teachers with perhaps an average of four years' experience. I picked them carefully, but more carefully than I picked the teachers, I selected the schools. Three of the four schoolhouses involved [two of the rooms were in the same building] were located in districts where not one parent in ten spoke English as his mother tongue. I sent home a notice to the parents and told them about the experiment that we were going to try, and asked any of them who objected to it to speak to me about it. I had no protests. Of course, I was fairly sure of this when I sent the notice out. Had I gone into other schools in the city where the parents were high school and college graduates, I would have had a storm of protest and the experiment would never have been tried. I had several talks with the teachers and they entered into the new scheme with enthusiasm.

The children in these rooms were encouraged to do a great deal of oral composition. They reported on books that they had read, on incidents which they had seen, on visits that they had made. They told the stories of movies that they had attended and they made up romances on the spur of the moment. It was refreshing to go into one of these rooms. A happy and joyous spirit pervaded them. The children were no longer under the restraint of learning multiplication tables or struggling with long division. They were thoroughly enjoying their hours in school.

At the end of eight months I took a stenographer and went into every fourth−grade room in the city. As we have semi−annual promotions, the children who had been in the advanced third grade at the time of the beginning of the experiment, were now in the first half of the fourth grade. The contrast was remarkable. In the traditional fourth grades when I asked children to tell me what they had been reading, they were hesitant, embarrassed, and diffident. In one fourth grade I could not find a single child who would admit that he had committed the sin of reading. I did not have a single volunteer, and when I tried to draft them, the children stood up, shook their heads, and sat down again. In the four experimental fourth grades the children fairly fought for a chance to tell me what they had been reading. The hour closed, in each case, with a dozen hands waving in the air and little faces crestfallen, because we had not gotten around to hear what they had to tell.

For some years I had noted that the effect of the early introduction of arithmetic had been to dull and almost chloroform the child's reasoning faculties. There was a certain problem which I tried out, not once but a hundred times, in grades six, seven, and eight. Here is the problem: "If I can walk a hundred yards in a minute [and I can], how many miles can I walk in an hour, keeping up the same rate of speed?"

In nineteen cases out of twenty the answer given me would be six thousand, and if I beamed approval and smiled, the class settled back, well satisfied. But if I should happen to say, "I see. That means that I could walk from here to San Francisco and back in an hour" there would invariably be a laugh and the children would look foolish.

I, therefore, told the teachers of these experimental rooms that I would expect them to give the children much practise in estimating heights, lengths, areas, distances, and the like. At the end of a year of this kind of work, I visited the experimental room which had had a combination of third− and fourth−grade children, who now were fourth and fifth graders. I drew on the board a rough map of the western end of Lake Ontario, the eastern end of Lake Erie, and the Niagara River. I asked them to guess what it was, and was not surprised when they identified the location. I then labeled three spots along the river with the letters "Q," "NF," and "B." They identified Niagara Falls and Buffalo without any difficulty, but were puzzled by the "Q." Some thought it was Quebec but others knew it was not. I finally told them that it was Queenstown. I then drew a cross section of the falls, showing the hard layer of rock above and the soft layer eating out underneath, and they told me what it was and why it was that the stone was falling, little by little, from the edge. They told me how this process was going on. I then made the statement that in 1680, when white men had first seen the falls, the falls were 2500 feet lower down than they are at present. I then asked them at what rate the falls were retreating upstream. These children, who had had no formal arithmetic for a year but who had been given practise in thinking, told me that it was 250 years since white men had first seen the falls and that, therefore, the falls were retreating upstream at the rate of ten feet a year. I then remarked that science had decided that the falls had originally started at Queenstown, and, indicating that Queenstown was now ten miles down the river, I asked them how many years the falls had been retreating. They told me that if it had taken the falls 250 years to retreat about a half mile, it would be at the rate of 500 years to the mile, or 5000 years for the retreat from Queenstown. The map had been drawn so as to show the distance from Niagara Falls to Buffalo as approximately twice the distance from Queenstown to Niagara Falls. Then I asked these children whether they had any idea how long it would be before the falls would retreat to Buffalo and drain the lake. They told me that it would not happen for another ten thousand years. I asked them how they got that and they told me that the map indicated that it was twenty miles from Niagara Falls to Buffalo, or thereabouts, and that this was twice the distance from Queenstown to Niagara Falls!

It so happened that a few days after this incident I was visiting a large New England city with five of my brother superintendents. Our host was interested in my description of this incident and suggested that I try the same problem on a fifth grade in one of his schools. With the other superintendents as audience, I stood before an advanced fifth grade in what was known as the Demonstration School, the school used for practise teaching and to which visitors were always sent.

> The home superintendent: Boys and girls, would you like to have Superintendent Benezet of Manchester, New Hampshire, ask you some questions about Niagara Falls?
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> *The children express pleasure at the idea.*
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> Mr. Benezet: [Drawing a map on the board] Children, what is this that I have drawn on the blackboard?

Children: The Great Lakes.
Mr. B.: Good. What lakes?
A child: Lake Ontario and Lake Erie.
Mr. B.: Good. What is the river?
Child: The St. Lawrence River.
Mr. B.: That is really correct. It is the St. Lawrence River. But they call it by a different name here. They call it the Niagara River. What have you heard in connection with the Niagara River?
Another child: Niagara Falls are there.
Another child: Niagara Falls are connected with Niagara River.
Mr. B.: Oh! How are they connected?
Child: The water trickles down the Falls and goes into the Niagara River.
Mr. B.: I should call that quite a trickle. Have any of you children seen Niagara Falls?

Three raise their hands.

Mr. B.: How high are the falls? Have you any idea? Are they higher than this room?
Children: Yes [dubiously].
Mr. B.: Well, how high is this room?

Its height is guessed anywhere from 11 feet to 40 feet. The room is actually about 16 feet high. The question of the height of the falls is finally dropped.

Mr. B.: Well, never mind how high the falls are. On this map here I have indicated one spot and marked it "NF," and another spot and marked it "B." What does "NF" mean?
Children: Niagara Falls.
Mr. B.: What does "B" stand for?
Another child: Bay.
Mr. B.: No. Remember that Niagara Falls is not only the name of the Falls, but the name of a city.
Child: Baltimore.

After considerable pause, the home superintendent, in the back of the room, tells the class that the name of the city is also the name of an animal.

Child: Buffalo.
Mr. B.: Yes. Now there is another town here that I am going to mark "Q." It is not Quebec; it is Queenstown. People who have studied this carefully tell us that once upon a time the falls were at Queenstown. Tell me now. What does it mean if I say that I show you the cross section of an apple?

Class is uncertain.

Mr. B.: Suppose that you cut an apple in half with a knife. What do I show you if I hold up one−half?
Child: Half the apple.
Another child: The core of the apple.
Third child: The inside of an apple.
Mr. B.: Tell me. Is the word "section" a new word to the majority of you?

Enthusiastic chorus of "No."

Mr. B.: Well, a cross−section of an apple means a cut right thru an apple. Why have I said this to you?

Meantime he has drawn on the board a cross−section of Niagara Falls.

Child: Because that is a cross−section of the falls.

Mr. Benezet now explains the two kinds of rock and asks which is the harder. They finally decide that the rock above is the harder. He then shows how the underneath rock rotted away, and that finally there was a shelf of hard rock overhanging. This became too heavy and fell off; and the falls have thereby moved back some ten feet.

Mr. B.: Now, when white men first saw the falls in 1680 [placing this date on the board], the falls were further down the river than they are now, and it is estimated that since that time they have moved back upstream about 2500 feet. Now how long ago was it that white men first saw the falls?
Child: Four hundred years.
Another child: Two hundred years.
Third child: Three hundred years.

Guesses range anywhere between 110 years and 450 years. One boy says it was about the time that Columbus sailed to America; another says that it was about the time of the Pilgrims and the Puritans.

Mr. B.: Well, how are we going to find out?

General bewilderment for a while. Finally:

Child: Take 1930 and subtract it from 1680.
Mr. B.: Fine.

He writes on the blackboard:

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1680
1930
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Mr. B.: Now take a look and tell me how many years that was. See if you can tell me before we subtract it, figure by figure.

It is to be noted that not one child called attention to the wrong position of the two sets of figures. They guess 350 years, 200 years, 400 years.

Mr. B.: Well, let's subtract it figure by figure.
Child: Zero from 0 equals 0. Three from 8 equals 5. Nine from 6 equals 3. Three hundred fifty years is the answer.
Mr. B.: How many think that 350 years is right?

About two−thirds of the hands go up. Finally two or three think that it is wrong.

Mr. B.: All right, correct it.

Child: It should have been 9 from 16 equals 7.

Mr. Benezet thereupon puts down 750 for the answer. When he asks how many in the room agree that this is right, practically every hand is raised. By this time the local superintendent was pacing the door at the rear of the room and throwing up his hands in dismay at this showing on the part of his prize pupils. After a time, as Mr. Benezet looks a little puzzled, the children gradually become a little puzzled also. One little girl, Elsie Miller, finally comes to the board, reverses the figures, subtracts, and says the answer is 250 years.

Mr. B.: All right. If the falls have retreated 2500 feet in 250 years, how many feet a year have the falls moved upstream?
Child: Two feet.

Mr. Benezet registers complete satisfaction and asks how many in the class agree. Practically the whole class put hands up again.

Mr. B.: Well, has anyone a different answer?
Child: Eight feet.
Another child: Twenty feet.

Finally Elsie Miller again gets up, and says the answer is ten feet.

Mr. B.: What? Ten feet? *(Registering great surprise)*

The class, at this, bursts into a roar of laughter. Elsie Miller sticks to her answer, and is invited by Mr. Benezet to come up and prove it. He says that it seems queer that Elsie is so obstinate when everyone is against her. She finally proves her point, and Mr. Benezet admits to the class that all the rest were wrong.

Mr. B.: Now, what fraction of a mile is it that the falls have retreated during the last 250 years?

Children guess 3/2, 3/4, 2/3, 1/20, 7/8 − everything except 1/2. The bell for dismissal rings and the session is over.

It will be noted that the local superintendent gave them a little hint at the outset, that was not given to the Manchester children, when he said, "Niagara Falls." They were prepared to identify my map. Also, the Manchester children who had not learned tables but had talked a great deal about distances and dimensions, recognized the fact that 2500 feet was about a half a mile, while the children in the larger city who were fresh from their tables, had little conception of the distance.

I was so delighted with the success of the experiment so far that in the fall of 1930 we started six or seven other rooms along the same line. The formal arithmetic was dropped and emphasis was placed on English expression, on reasoning, and estimating of distances.

One day I tried an experiment having to do with English expression. I hung before a 7−B class a copy of a painting by Frederick Waugh, representing a polar bear floating on a small berg of ice. This was a traditionally taught room in a school where there were very few children of foreign extraction. I asked the children to write anything which they felt inspired to put down as a result of seeing the picture. Three quarters of an hour later I hung the same picture before another 7−B grade, one of the experimental groups this time, in a school where not more than three children in the room came from homes where English was the language of the parents. I then called the seventh−grade teachers of the city together and read them the ten best papers from one room and the ten best from the other. I asked them if they saw any difference. One teacher remarked that one group was about a year and a half or two years ahead of the other in maturity of expression, and there was general assent to this statement. I said to the teachers, "If I should tell you that one group came from the "A" school and the other from the "B," from which school would you guess the better group of papers came?"

"Oh, the "A" school, undoubtedly," said they, naming the school whose patrons speak English in their homes.

"Well," I said, "it was just the other way," and there was a murmur of incredulity. Then we analyzed the papers and counted the number of adjectives used by the traditionally taught pupils. There were forty all told: nice, pretty, blue, green, cold, etc. We then counted the adjectives used by the other group [the number of papers was approximately the same] and we found 128, including magnificent, awe−inspiring, unique, majestic, etc. The little Greeks, Armenians, Poles, and French−Canadians had far surpassed their English−speaking opponents.

I next tried a rather similar test. I hung the same picture − a landscape representing a river scene in the vicinity of Manchester − before ten different fifth−grade rooms. Five of them had been brought up under the old traditional curriculum and five of them were of the experimental group. It was the same story: the experimental rooms far excelled the others in fluency of expression. They used words that the others had never heard of. Nevertheless, when we came to test the papers for spelling, the poorest of the experimental rooms exactly tied the record of the best of the traditional groups. The most surprising result came in a certain room in which there was housed a 5−B grade and a 5−A. The younger pupils, the 5−B's, had been brought up under the experimental curriculum, without arithmetic, while the other half of the room were traditional. The 5−A's made the poorest record of all the ten groups while the 5−B's, the younger group, were next to the top. For four months they had been taught by the same teacher but by different methods.

Now we were ready to experiment on a much larger scale. By the fall of 1932 about one−half of the third−, fourth−, and fifth−grade rooms in the city were working under the new curriculum. Some of the principals were a little dubious and asked permission to postpone formal arithmetic until the beginning of the sixth grade instead of the beginning of the seventh. Accordingly, permission was given to four schools to begin the use of the arithmetic book with the 6−B grade. About this time Professor Guy Wilson of Boston University asked permission to test our program. One of our high school teachers was working for her master's degree at Boston University and as part of her work he assigned her the task of giving tests in arithmetic to 200 sixth grade children in the Manchester schools. They were divided fairly evenly, 98 from experimental rooms and 102 from the traditional groups, or something like that. These were all sixth graders. Half of them had had no arithmetic until beginning the sixth grade and the other half had had it throughout the course, beginning with the 3−A. In the earlier tests the traditionally trained people excelled, as was to be expected, for the tests involved not reasoning but simply the manipulation of the four fundamental processes. By the middle of April, however, all the classes were practically on a par and when the last test was given in June, it was one of the experimental groups that led the city. In other words these children, by avoiding the early drill on combinations, tables, and that sort of thing, had been able, in one year, to attain the level of accomplishment which the traditionally taught children had reached after three and one−half years of arithmetical drill. [This article will be continued in the December issue.]

Part II | Part III
Benezet Centre