Long before the advent of the National Curriculum, **Warwick Sawyer** was using and applying mathematics in his classroom.

MATHEMATICS, EMOTIONS AND THINGS

I have recently published a series of articles dealing with an approach to algebra that I originally worked out with a class of 9 - 10-year-olds. These articles, I believe, contain some quite useful ideas for teaching in a reasonably tranquil situation. The thought kept crossing my mind; will not these articles appear as a complete waste of journal space to a teacher dealing with a situation that is anything but tranquil – say, in a region where school-leavers expect to be unemployed, where there is a general hostility to authority, so that truancy, rebellion and even violence are always possible. I am not in any way proposing a panacea to meet this situation, but it seems to me that certain considerations, which I have put forward for many years, have some relevance to such conditions, and certainly elsewhere to the milder problem when we have considerable doubt whether the pupils really want to be in the classroom at all.

The decisive factor in any lesson is the extent (if any) to which the teacher's presentation has awakened in a class the desire to learn. In this connection it is helpful to take a brief glance at another subject and compare two approaches to teaching a foreign language.

The first of these I heard about some years ago from inspectors. It concerned a primary school teacher in Cheshire of whom they had a high opinion. She took it into her head that the children should be given an introduction to French. When the inspector entered the classroom she was cycling in it and the children were playing the role of French traffic policemen. It is evident the experience reverberated in their minds; they must have gone home and told their parents, "When we said *à droit* she went to the right and if we said *à gauche* she went to the left." It evidently created a splendid mood for any further lessons.

The other approach was that of a French textbook inflicted on us when I was a boy. It began with a story about two boys who hated work. Their father took them into the garden. "See the bees! They are not idle. The ants too! Every creature has to work." It was assumed that after exposure to this moral tale, we would start memorising irregular verbs with tremendous energy. It would be an interesting topic for research to try to find out if any child anywhere was ever motivated to work by this story.

The reason for its failure is that it uses argument; it is directed towards the superficial, reasoning, conscious part of the mind, not to the depths from which purposeful drives emanate. Being interested in something is a feeling, an emotion. Our emotions are not at our beck and call. It is no use me saying, "I will tell you a story and you must try hard to be amused." Interest, like laughter and falling in love, is something that happens to us. Education results when adults are able to find the approach that will unlock the energy within a child and steer it into useful, or at least harmless, channels. This diversion of energy into acceptable channels is one of the most important aspects of teaching; it is a civilising influence, and such influences have never been more needed than to-day.

I do not suppose the lady in Cheshire brought her bicycle with her for further lessons in French. The importance of the first lesson is that it creates the atmosphere for all subsequent lessons. The first lesson in a new school or with a new teacher should always be planned more for its dramatic impact than for its academic content.

In thinking about teaching it is always useful to remember the time when you were a pupil. I remember as a child there were some subjects I revelled in. I would read books about them out of school. Any fact I learned I stored up for future use. There were other subjects I found completely without purpose. I did not try to do badly in them but it usually happened that my performance was well below satisfactory. I am convinced that any attempt to teach a topic to uninterested pupils both puts a strain on the teacher and is without benefit to the learners.

The search for a stimulus

The need to have different approaches to different classes is obvious. There can be a total difference of attitude in two maths sets at the same school. I once met a characteristic example of this. The occasion was a crisis in a girls' grammar school in Leicester. The head of mathematics became ill shortly before an important examination, and a number of us from the College of Technology were brought in to meet the emergency. I taught geometry to two of the mathematics sets, the strongest and the weakest. Set S (S for 'superior') reacted to geometry much as I did. They found it intellectually stimulating, a puzzle, a challenge. Teaching them was no problem. In the other set this interest was entirely lacking; their concerns seemed to be artistic rather than intellectual. They came alive only when we started experimenting with coloured geometrical patterns. It is quite possible that they had been ill-advised to embark on a course where the whole emphasis was on strict, formal logic.

Classes and individuals differ so much that there can be no general rule for finding an effective approach, and indeed sometimes this may be difficult or even impossible. There are however two easily recognisable types of pupils, whose needs most schools fail to meet. For the last fifty years or more I have been trying to draw attention to these. They are (i) the very able pupil who is driven to desperation by – what he or she sees as – the snail's pace of normal class teaching, (ii) the pupil who responds strongly to actual objects and experiences, and hardly at all to words and symbols. This article deals only with the second type of pupil.

The hope becomes reality

For many years I had believed that it should be possible to have a school in which pupils worked naturally and did not have to be continuously chivvied along by teachers. In the years 1937-1944 I saw such a school in action. It was in Prestolee, a little mill-town between Manchester and Bolton, a school for ages 5 to 14, under the control of the Lancashire County Council. It was organised as a library and a workshop. When you visited it, children were moving around, looking up information they needed or engaged in practical work, which had altered the whole appearance of the school building and the playground. This school gave the opportunity to all pupils to advance at whatever rate corresponded to their academic ability, and all were involved in a variety of practical pursuits. The school was ornamented with notices (made by the pupils of course) one of which read 'We learn by doing'. I visited this school frequently, and was struck by its extraordinarily peaceful atmosphere [5].

These visits later influenced me very strongly in various attempts I made to help pupils who reacted to things rather than to words. This article describes some of these experiences.

Experimental teaching, 1943-4

In 1943-4 I taught a class of 24 eleven-year-old boys for one afternoon a week. They were in a B-stream class in a secondary modern school. What this meant was that there was no way they could have been academically lower. There were a number of quite bright boys, who later on were very helpful to me as leaders of small activity groups.

Getting such groups organised was by no means easy. The school followed the ancient ideal of paralysis in excelsis. The boys were expected to sit motionless at their desks. They were full of energy, and I took every opportunity to let them move around. They had, of course, never had any training in individual activities, and the first result of letting them leave their desks was a good imitation of chaos.

To get a chance to talk quietly to individuals, I told them they could go into the playground and play football if they wanted to. I started some activity in the classroom and observed how many came in. Gradually the activities won over the football. An entry in my records; – '1st February 1944. Two boys were throwing things about. I said to them, if you want to run about, go outside and play football. They regarded this as a punishment!'

An early occasion on which everyone came into the classroom was when I did something that I perhaps would not do in the altered circumstances of today. I brought along a collection of tin cans and scraps of wood and said, "To-day I will show you how to make time-bombs." These were in fact nothing more dangerous than a water-clock arranged so that a stick fell down at a certain stage, (1, pp 43-44). That night the boys were out in the streets showing boys from other schools how to make these. The prestige of the school rose tremendously. The boys had been taught something they thought worth knowing.

I did not go into the mathematical aspects of water-clocks as I might have done with a stronger class.* My object was simply to make them look forward to the lessons, and to dispel their unspoken assumption that anything they enjoyed doing had to be done secretly under the desk, because the teacher would disapprove of it.

The class made various things which were much more conventional. Among these were a quoit board to hang on the wall with hooks marked from 1 to 13, that three boys made. This gave practice in adding numbers. Others played quoits on the floor with rope rings. They had bored a hole in a piece of wood and placed a dowel in it so it stood upright. This gives a number sense at a more primitive level. If you throw 3 rings at a time with a target of 10, and have scored 7 only while your opponent has 9, you know it is highly desirable to get all 3 on.

Getting material was difficult. I brought along my carpentry tools and any scraps of wood I could find.

The difficulty of listening to all 24 of them at the same time led to something I had not foreseen, that perhaps had some value. If a boy wanted something next time, he had to write me a note – please bring 6 one-inch nails, or whatever it was.

I had the impression that in many of their homes there was absolutely nothing except the bare necessities of life. This probably explained why they were able to be interested in very simple things. It would not be so to-day.

Leicester College of Technology, 1945-1947

In these years we taught at all levels from unskilled workers to research chemists, giving each the mathematics appropriate to their occupation. Somewhere between these extremes came engineering apprentices studying for Ordinary National Certificate.

This was an excellent testing ground for any teaching innovation. We had no control at all of the syllabus, the examination and the marking. In a technical institution you have to succeed. If too many students fail, the employers stop sending them to you.

Howard Joint, who was head of the mathematics department, had come to the conclusion that apprentices were expected to learn mathematics in a foreign language. Teachers and textbooks used words and symbols. The apprentices thought, so to speak, with their hands and their eyes. He began to make increasing use of material aids.

For instance, the apprentices had to know that the area of a circle was proportional to the square of the radius. He had circular discs made from a sheet of metal. A disc was weighed. The class were then asked how heavy a disc with double the diameter would be. They said, twice as much, but when weighed it was 4 times as much. This proved much more effective than a verbal explanation; this was their world, in which the behaviour of real things was seen.

Later Howard left to become principal of another college and I took over the mathematics department and the development of this idea. Excellent teachers were attracted by this project and eventually we were able to present every topic in the ONC syllabus by some object or mechanism. When the scheme was sufficiently advanced the appearance of the room had a significant effect. The apprentices would enter, expecting to see a conventional mathematics classroom with nothing except blackboard and chalk. Instead they found themselves surrounded by gadgets of every kind, [2].

Sometimes these objects, like the discs for weighing, were simply a means of communicating some mathematical idea. But we had also had models that, besides doing this, were related to engineering equipment or to the students' outside interests. One such model had to do with designing the steering mechanism of a motor-car. When a car is turning the front wheels are not parallel. The angles through which they are rotated must always be in a certain relation if there is not to be excessive wear on the tyres. The model enabled the students to draw a graph showing how the angles should be related.

The model we actually used was a very realistic one made from steel. It is possible to make a very simple device from cardboard that conveys the essential principle, which might well interest any class interested in cars. The details can be found in *The search for pattern* [3].

We wanted our students to feel involved in the project so we asked them to suggest ideas for models. During the war they had developed a strong interest in aircraft. One youth suggested what he called a tethered aeroplane – a model aeroplane that would fly in circles around a post. It was to have a propeller driven by a twisted rubber band. We had such a model made. If an inspector had asked us, what mathematics we derived from it, we would have said we did not know. We thought morale would improve when something connected with students' hobbies was seen in the classroom. In time we found things to do with it. One activity was to make a graph showing the relation between the number of turns put on the rubber and the number of times the aeroplane flew round before coming to rest. Also it would be possible to start an argument about how fast it was flying (extremely difficult to guess) and calculate the speed.

We had 24 apprentices in a class. After we had been working on this project for about two years, we had reached the stage at which the class on first entering found six tables, on each of which there was an experiment from which they could discover some useful mathematical result. Four students could work at each table. They moved from table to table until all of them had done all the experiments. After this we had more conventional lessons, with the teacher demonstrating some device to explain a mathematical idea. It took a lot of painstaking work to arrive at this stage. Sometimes we would read a whole book on some aspect of engineering and find only one or two examples suitable for such a class.

Canada, 1965-1976

In Canada I learned of an interesting device from one of my student teachers, Richard Carruthers. He had been in Voluntary Service Overseas and wanted to show students in Africa how mathematics could help in everyday tasks. He constructed a parabolic mirror by pasting metal foil onto a cardboard framework. This was then used as a solar oven for cooking meals [4, p32].

Later he did his Canadian teaching practice. His pupils made a solar oven about a metre in diameter. They went out on a cold day. The temperature was −11°C and there was snow on the ground. They put a panful of snow at the focus of the mirror. In 5 minutes it became boiling water. They made coffee and drank it.

I imagine this experience stayed rather more vividly in their memory than many other lessons.

Another device that proved useful appears in books as 'an electronic metronome'. It contains a couple of transistors, a capacitor and a loudspeaker. It has 2 terminals. If a resistor is connected between these clicks are heard. The number of clicks per minute is given by a simple law, perhaps 6,000,000 divided by the resistance in ohms. This law can be discovered or a graph drawn. The resistance of the human body lies in the appropriate range so pupils can find their own resistance by grasping the terminals and counting the clicks.

We tried this out with a class of 17-year-old youths in a school that catered for those who had not fitted comfortably into the regular classroom, and had a very successful hour. Their teacher attributed this success to two things. The device involved transistors and for most of this class their most treasured and romantic possession was a transistor radio. Also human beings are interested in themselves, so they found a certain fascination in measuring their own resistance.

One youth was rather alarmed. His resistance was vastly below that of anyone else in the class. Did this mean he was in danger of sudden death? We explained to him that it simply meant that his hands were unusually moist. The effect of perspiration in reducing electrical resistance is the basis of some so-called 'lie-detectors'; stress often causes an increase in perspiration. There is also a useful safety lesson; it is much more dangerous to touch high-voltage wires when your hands are wet. The rapidity of the clicks increases dramatically if the hands are wetted. One Canadian teacher used minimum effort when producing evidence that mathematics learning could be improved by contact with real objects. Many Canadian schools have excellent engineering facilities. He found that work in mathematics was improved by the simple expedient of having mathematics lessons taught in the engineering workshop.

Drastic overhaul?

The case for relating mathematics to real objects was put in the strongest possible manner by the very outspoken report, *Secondary education*, of the Scottish Education Department in 1947.

"We are in no doubt that Mathematics in Scottish Schools needs a drastic overhaul ... It is the great central mass of boys and girls, ranging from the Cs well up into the B group, who have fared badly, and the dullness and futility of much school teaching of the subject has been thrown into relief by the remarkable interest shown and progress made by many of these same pupils" [ie those whose work in school had been poor] "in the mathematical work of the Air Training Corps".

Primary schools have recognised the value of working with things, as reported in that marvellous book *Mathematics in primary schools*. The idea that this is no longer needed in secondary schools is entirely incorrect.

To the best of my knowledge there has not been a drastic overhaul of secondary education in Scotland or anywhere else. There are evidently great practical difficulties in making such a radical change. We cannot expect any sudden revolution. We need to initiate projects on a small scale, make the results known, and hope they will be taken up more widely.

It is clear that some schools are already making some changes in the desired direction. It would be most valuable to have a list of these made.

Anyone starting out in an unexplored direction is likely to make mistakes. It is important that these should not lead to a backlash or get the innovator the sack. Initial experiments should be on a small scale, and perhaps might be made in a maths club outside the regular curriculum.

While, as the report says, a changed approach may help quite able pupils, it might be wise to start with one or two pupils who are making no progress at all at present. There is very little risk that they will be harmed by this and they may well appreciate the fact that someone is paying attention to them.

*Is the time doubled if the diameter of the tin is doubled? No, it is multiplied by 4. Is it doubled if the height of the tin is doubled? No, it is multiplied by $\sqrt{2}$. Problem; would it be practicable to make one that ran all night and pulled the bedclothes off you in the morning?

References

1 W W Sawyer and L G Srawley, *Designing and making*, Blackwell, 1957.
2 W W Sawyer, Editor, *Mathematics in theory and practice*, Odhams, 1950.
3 W W Sawyer, *The search for pattern*, Penguin Books, 1970, pages 30-32.
4 W W Sawyer, *Integrated mathematics scheme, Book C*, Bell & Hyman, 1982.
5 Photographs of Prestolee School, books written by the children there, and descriptive documents can be seen in a permanent collection, housed in the School of Education, University of East Anglia.

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