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Messing About in Science (1965)

> "Nice? It's the *only* thing," said the Water Rat solemnly, as he leant forward for his stroke. "Believe me, my young friend, there is *nothing*-absolutely nothing-half so much worth doing as simply messing about in boats. Simply messing," he went on dreamily, "messing-about-in-boats-messing-"
>
> Kenneth Grahame
> *The Wind in the Willows*

As a college teacher, I have long suspected that my students' difficulties with the intellectual process come not from the complexity of college work itself, but mainly from their home background and the first years of their formal education. A student who cannot seem to understand the workings of the Ptolemaic astronomy, for example, turns out to have no evident acquaintance with the simple and "obvious" relativity of motion, or the simple geometrical relations of light and shadow. Sometimes for these students a style of laboratory work which might be called "Kindergarten Revisited" has dramatically liberated their intellectual powers. Turn on your heel with your head back until you *see* the ceiling-turn the other way-and don't fall over!

In the past two years, working in the Elementary Science Study, I have had the experience, marvelous for a naive college teacher, of studying young children's learning in science. I am now convinced that my earlier suspicions were correct. In writing about these convictions, I must acknowledge the strong influence on me by other staff members in the Study. We came together from a variety of backgrounds-college, high school, and elementary school teachers-and with a variety of dispositions toward science and toward teaching. In the course of trial teaching and of inventing new curricular materials, our shop talks brought us toward some consensus but we still had disagreements. The outline of ideas I wish to present here is my own, therefore, and not that of the group which has so much influenced my thinking. The formulation I want to make is only a beginning. Even if it is right, it leaves many questions unanswered, and therefore much room for further disagreement. In so complex a matter as education, this is as it should be. What I am going to say applies, I believe, to all aspects of elementary education. However, let me stick to science teaching.

My outline is divided into three patterns or phases of school work in science. These phases are different from each other in the relations they induce between children, materials of study, and teachers. Another way of putting it is that they differ in the way they make a classroom look and sound. My claim is that good science teaching moves from one phase to the other in a pattern which, though it will not follow mechanical rules or ever be twice the same, will evolve according to simple principles. There is no necessary order among these phases, and for this reason, I avoid calling them I, II, and III, and use instead some mnemonic signs which have, perhaps, a certain suggestiveness: O, Δ, and [].

O Phase. There is a time, much greater in amount than commonly allowed, which should be devoted to free and unguided exploratory work (call it play if you wish; I call it work). Children are given materials and equipment-*things*-and are allowed to construct, test, probe, and experiment

without superimposed questions or instructions. I call this O phase "Messing About," honoring the philosophy of the Water Rat, who absentmindedly ran his boat into the bank, picked himself up, and went on without interrupting the joyous train of thought:

> "-about in boats-or *with* boats. . . In or out of 'em, it doesn't matter. Nothing seems really to matter, that's the charm of it. Whether you get away, or whether you don't; whether you arrive at your destination or whether you reach somewhere else, or whether you never get anywhere at all, you're always busy, and you never do anything in particular: and when you've done it there's always something else to do, and you can do it if you like, but you'd much better not."

In some jargon, this kind of situation is called "unstructured," which is misleading; some doubters call it chaotic, which it need never be. "Unstructured" is misleading because there is always a kind of structure to *what* is presented in a class, as there was to the world of boats and the river, with its rushes and weeds and mud that smelled like plumcake. Structure in this sense is of the utmost importance, depending on the children, the teacher, and the backgrounds of all concerned.

Let me cite an example from my own recent experiences. Simple frames, each designed to support two or three weights on strings, were handed out one morning in a fifth-grade class. There was one such frame for each pair of children. In two earlier trial classes, we had introduced the same equipment with a much more "structured" beginning, demonstrating the striking phenomenon of coupled pendulums and raising questions about it before the laboratory work was allowed to begin. If there was guidance this time, however, it came only from the apparatus-a pendulum is to swing! In starting this way I, for one, naively assumed that a couple of hours of "Messing About" would suffice. After two hours, instead, we allowed two more and, in the end, a stretch of several weeks. In all this time, there was little or no evidence of boredom or confusion. Most of the questions we might have planned for came up unscheduled.

Why did we permit this length of time? First, because in our previous classes we had noticed that things went well when we veered toward "Messing About" and not as well when we held too tight a rein on what we wanted the children to do. It was clear that these children had had insufficient acquaintance with the sheer phenomena of pendulum motion and needed to build an apperceptive background, against which a more analytical sort of knowledge could take form and make sense. Second, we allowed things to develop this way because we decided we were getting a new kind of feedback from the children and were eager to see where and by what paths their interests would evolve and carry them. We were rewarded with a higher level of involvement and a much greater diversity of experiments. Our role was only to move from spot to spot, being helpful but never consciously prompting or directing. In spite of -because of!- this lack of direction, these fifth-graders became very familiar with pendulums. They varied the conditions of motion in many ways, exploring differences in length and amplitude, using different sorts of bobs, bobs in clusters, and strings, etc. And have *you* tried the underwater pendulum? They did! There were many sorts of discoveries made, but we let them slip by without much adult resonance, beyond our spontaneous and manifest enjoyment of the phenomena. So discoveries were made, noted, lost, and made again. I think this is why the slightly pontifical phrase "discovery method" bothers me. When learning is at the most fundamental level, as it is here, with all the abstractions of Newtonian mechanics just around the corner, don't rush! When the mind is evolving the abstractions which will lead to physical comprehension, all of us must cross the line between ignorance and insight many times before we truly understand. Little facts, "discoveries" without the growth of insight, are *not* what we should

seek to harvest. Such facts are only seedlings and should sometimes be let alone to grow into...

I have illustrated the phase of "Messing About" with a constrained and inherently very elegant topic from physics. In other fields, the pattern will be different in detail, but the essential justification is the same. "Messing About" with what can be found in pond water looks much more like the Water Rat's own chosen field of study. Here, the implicit structure is that of nature in a very different mood from what is manifest in the austerities of things like pendular motion or planet orbits. And here, the need for sheer acquaintance with the variety of things and phenomena is more obvious, before one can embark on any of the roads toward the big generalizations or the big open questions of biology. Regardless of differences, there is a generic justification of "Messing About" that I would like, briefly, to touch upon.

This phase is important, above all, because it carries over into school that which is the source of most of what children have already learned, the roots of their moral, intellectual, and esthetic development. If education were defined, for the moment, to include everything that children have learned since birth, everything that has
come to them from living in the natural and the human world, then by any sensible measure what has come before age five or six would outweigh all the rest. When we narrow the scope of education to what goes on in schools, we throw out the method of that early and spectacular progress at our peril. We know that five-year-olds are very unequal in their mastery of this or that. We also know that their histories are responsible for most of this inequality, utterly masking the congenital differences except in special cases. This is the immediate fact confronting us as educators in a society committed, morally and now by sheer economic necessity, to universal education.

To continue the cultivation of earlier ways of learning, therefore; to find *in school* the good beginnings, the liberating involvements that will make the kindergarten seem a garden to the child and not a dry and frightening desert, this is a need that requires much emphasis on the style of work I have called O, or "Messing About." Nor does the garden in this sense end with a child's first school year, or his tenth, as though one could then put away childish things. As time goes on, through a good mixture of this with other phases of work, "Messing About" evolves with the child and thus changes its quality. It becomes a way of working that is no longer childish though it remains always childlike, the kind of self-disciplined probing and exploring that is the essence of creativity.

The variety of the learning-and of inhibition against learning-that children bring from home when school begins is great, even within the limited range of a common culture with common economic background (or, for that matter, within a single family). Admitting this, then if you cast your mind over the whole range of abilities and backgrounds that children bring to kindergarten, you see the folly of standardized and formalized beginnings. We are profoundly ignorant about the subtleties of learning but one principle ought to be asserted dogmatically: That there must be provided some continuity in the content, direction, and style of learning. Good schools begin with what children have *in fact* mastered, probe next to see what *in fact* they are learning, continue with what *in fact* sustains their involvement.

Δ Phase. When children are led along a common path, there are always the advanced ones and always the stragglers. Generalized over the years of school routine, this lends apparent support to the still widespread belief in some fixed, inherent levels of "ability," and to the curious notions of "under-" and "over-achievement." Now, if you introduce a topic with a good deal of "Messing About," the variance does not decrease, it increases. From a conventional point of view, this means

the situation gets worse, not better. But I say it gets better, not worse. If after such a beginning you pull in the reins and "get down to business," some children have happened to go your way already, and you will believe that you are leading these successfully. Others will have begun, however, to travel along quite different paths, and you have to tug hard to get them back on to yours. Through the eyes of these children you will see yourself as a dragger, not a leader. We saw this clearly in the pendulum class I referred to; the pendulum being a thing which seems deceptively simple but which raises many questions in no particular order. So the path which each child chooses is his best path.

The result is obvious, but it took me time to see it. If you once let children evolve their own learning along paths of their choosing, you then must see it through and *maintain* the individuality of their work. You cannot begin that way and then say, in effect, "That was only a teaser," thus using your adult authority to devalue what the children themselves, in the meantime, have found most valuable. So if "Messing About" is to be followed by, or evolve into, a stage where work is more externally guided and disciplined, there must be at hand what I call "Multiply Programmed" material; material that contains written and pictorial guidance of some sort for the student, but which is designed for the greatest possible variety of topics, ordering of topics, etc., so that for almost any given way into a subject that a child may evolve on his own, there is material available which he will recognize as helping him farther along that very way. Heroic teachers have sometimes done this on their own, but it is obviously one of the places where designers of curriculum materials can be of enormous help, designing those materials with a rich variety of choices for teacher and child, and freeing the teacher from the role of "leader-dragger" along a single preconceived path, giving the teacher encouragement and real logistical help in diversifying the activities of a group. Such material includes good equipment, but above all, it suggests many beginnings, paths from the familiar into the unknown. We did not have this kind of material ready for the pendulum class I spoke about earlier and still do not have it. I intend to work at it and hope others will.

It was a special day in the history of that pendulum class that brought home to me what was needed. My teaching partner was away (I had been the observer, she the teacher). To shift gears for what I saw as a more organized phase of our work, I announced that for a change we were all going to do the same experiment. I said it firmly and the children were, of course, obliging. Yet, I saw the immediate loss of interest in part of the class as soon as my experiment was proposed. It was designed to raise questions about the *length* of a pendulum, when the bob is multiple or odd-shaped. Some had come upon the germ of that question; others had had no reason to. As a college teacher I have tricks, and they worked here as well, so the class went well, in spite of the unequal readiness to look at "length." We hit common ground with rough blackboard pictures, many pendulums shown hanging from a common support, differing in length and the shape and size of bobs. Which ones will "swing together"? Because their eyes were full of real pendulums, I think, they could *see* those blackboard pictures swinging! A colloquium evolved which harvested the crop of insights that had been sowed and cultivated in previous weeks. I was left with a hollow feeling, nevertheless. It went well where, and only where, the class found common ground. Whereas in "Messing About" all things had gone uniformly well. In staff discussion afterward, it became clear that we had skipped an essential phase of our work, the one I am now calling Δ phase, or Multiply Programmed.

There is a common opinion, floating about, that a rich diversity of classroom work is possible only when a teacher has small classes. "Maybe *you* can do that; but you ought to try it in my class of 43!" I want to be the last person to belittle the importance of small classes. But in this particular case, the statement ought to be made that in a large class one cannot afford *not* to diversify children's work-or rather *not* to allow children to diversify, as they inevitably will, if given the chance. So-called

"ability grouping" is a popular answer today, but it is no answer at all to the real questions of motivation. Groups which are lumped as equivalent with respect to the usual measures are just as diverse in their tastes and spontaneous interests as unstratified groups! The complaint that in heterogeneous classes the bright ones are likely to be bored because things go too slow for them ought to be met with another question: Does that mean that the slower students are *not* bored? When children have no autonomy in learning everyone is likely to be bored. In such situations the overworked teachers have to be "leader-draggers" always, playing the role of Fate in the old Roman proverb: "The Fates lead the willing; the unwilling they drag."

"Messing About" produces the early and indispensible autonomy and diversity. It is good-indispensible-for the opening game but not for the long middle game, where guidance is needed; needed to lead the willing! To illustrate once more from my example of the pendulum, I want to produce a thick set of cards-illustrated cards in a central file, or single sheets in plastic envelopes-to cover the following topics among others:

1. Relations of amplitude and period.
2. Relations of period and weight of bob.
3. How long is a pendulum (odd-shaped bobs)?
4. Coupled pendulums, compound pendulums.
5. The decay of the motion (and the idea of half-life).
6. String pendulums and stick pendulums-comparisons.
7. Underwater pendulums.
8. Arms and legs as pendulums (dogs, people, and elephants).
9. Pendulums of other kinds-springs, etc.
10. Bobs that drop sand for patterns and graphs.
11. Pendulum clocks.
12. Historical materials, with bibliography.
13. Cards relating to filmloops available, in class or library.
14. Cross-index cards to other topics, such as falling bodies, inclined planes, etc.
15 -75. Blank cards to be filled in by classes and teachers for others.

This is only an illustration; each area of elementary science will have its own style of Multiply Programmed materials. Of course, the ways of organizing these materials will depend on the subject. There should always be those blank cards, outnumbering the rest.

There is one final warning. Such a file is properly a kind of programming-but it is not the base of rote or merely verbal learning, taking a child little step by little step through the adult maze. Each item is simple, pictorial, and it guides by suggesting further explorations, not by replacing them. The cards are only there to relieve the teacher from a heroic task. And they are only there because there are apparatus, film, library, and raw materials from which to improvise.

[] Phase. In the class discussion I referred to, about the meaning of *length* applied to a pendulum, I was reverting back to the college teacher habit of lecturing; I said it went very well in spite of the lack of Multiply Programmed background, one that would have taken more of the class through more of the basic pendulum topics. It was not, of course, a lecture in the formal sense. It was question-and answer, with discussion between children as well. But still, I was guiding it and fishing for the good ideas that were ready to be born, and I was telling a few stories, for example, about Galileo. Others could do it better. I was a visitor, and am still only an amateur. I was successful then

only because of the long build-up of latent insight, the kind of insight that the Water Rat had stored up from long afternoons of "Messing About" in boats. It was more than he could ever have been told, but it gave him much to tell. This is not all there is to learning. of course; but it is the magical part, and the part most often killed in school. The language is not yet that of the textbook, but with it even a dull-looking textbook can come alive. One boy thinks the length of a pendulum should be measured from the top to what he calls the "center of gravity." If they have not done a lot of work with balance materials, this phase is for most children only the handle of an empty pitcher, or a handle without a pitcher at all. So I did not insist on the term. Incidentally, it is not quite correct physics anyway, as those will discover who work with the stick pendulum. Although different children had specialized differently in the way they worked with pendulums, there were common elements, increasing with time, which would sustain a serious and extended class discussion. It is this pattern of discussion I want to emphasize by calling it a separate, O phase. It includes lecturing, formal or informal. In the above situation, we were all quite ready for a short talk about Ga1ileo, and ready to ponder the question whether there was any relation between the way unequal weights fall together and the way they swing together when hanging on strings of the same length. Here we were approaching a question-a rather deep one, not to be disposed of in fifteen minutes-of theory, going from the concrete perceptual to the abstract conceptual. I do not believe that such questions will come alive either through the early "Messing About" or through the Multiply Programmed work with guiding questions and instructions. I think they come primarily with discussion, argument, the full colloquium of children and teacher. Theorizing in a creative sense needs the content of experience and the logic of experimentation to support it. But these do not automatically lead to conscious abstract thought. Theory is square! []

We of the Elementary Science Study are probably identified in the minds of those acquainted with our work (and sometimes perhaps in our own minds) with the advocacy of laboratory work and a free, fairly O style of laboratory work at that. This may he right and justified by the fact that prevailing styles of science teaching are [] most of the time, much too much of the time. But what we criticize for being too much and too early, we must work to re-admit in its proper place.

I have put O, Δ, and [] in that order, but I do not advocate any rigid order; such phases may be mixed in many ways and ordered in many ways. Out of the colloquium comes new "Messing About." Halfway along a programmed path, new phenomena are accidentally observed. In an earlier, more structured class, two girls were trying obediently to reproduce some phenomena of coupled pendulums I had demonstrated. I heard one say. "Ours isn't working right." Of course, pendulums never misbehave; it is not in their nature; they always do what comes naturally, and in this case, they were executing a curious dance of energy transference, promptly christened the "twist." It was a new phenomenon, which I had not seen before, nor had several physicists to whom, in my delight. I later showed it. Needless to say, this led to a good deal of "Messing About," right then and there.

What I have been concerned to say is only that there are, as I see it, three major phases of good science teaching; that no teaching is likely to be optimal which does not mix all three; and that the one most neglected is that which made the Water Rat go dreamy with joy when he talked about it. At a time when the pressures of prestige education are likely to push children to work like hungry laboratory rats in a maze, it is good to remember that their wild; watery cousin, reminiscing about the joys of his life, uttered a profound truth about education.