Richard Butt

Elementary School Science

A progressive plan for classroom change

In how many thousands of classrooms in the last decade or two have teachers, inspired by the intrinsic appeal of some curricular innovation, come to grief over the behaviour of students reacting to novel demands on their self-control? If only children could take unaccustomed freedoms calmly! Richard Butt, aware that problems of implementation in the classroom have more or less broken the back of the first curricular reform movement in science education, reports a second and more realistic movement now under way; but he still finds inadequate its concern for the complexities of transition at the classroom level. He presents an illustration in detail of a "transitional curriculum", that will enable a traditional class and its teacher to learn by small stages certain necessary new relationships and social disciplines, at the same time as they are inducted gradually into the manipulations, problem-solvings, and team-work involved in an inquiry-oriented curriculum.

Many new elementary science curricula were developed during the curriculum reform movement in North America in the 1960s. Amidst this post-sputnik flurry the focus was on development. For most of a decade, university experts and central office administrators blithely assumed that the new curricula were being successfully implemented, for these new curricula, developed for the most part from sophisticated conceptual schemes by university experts, were supposed to be "teacher proof." In other words, given simple enough instructions and sufficient in-service preparation, any teacher could teach the program without ruining its intent. This attitude endured even when many evaluative studies failed to show expected achievement gains.[1] Researchers, puzzled by the lack of better achievement among children who had been "taking" the new programs, carefully refined their tools and research designs and started again.

This writer and a colleague were involved in one such effort in the early 1970s.[2] We felt that in comparing the old to the new program we should ensure that classes were actually practising the distinct intentions of each program. When we observed classes in action we found very few which could be said to have fully implemented the new approaches. In fact, in general there was very little difference between classrooms supposedly following the new approach and those following "traditional" programs. Across North America, other such findings began to emerge, so much so that Charters and Jones[3] called the widespread and inconclusive evaluation studies of the impact of the curriculum reform movement *the appraisal of non-events.* After several years of mounting evidence it is now clear, and grudgingly admitted, that this curriculum reform movement has failed.[4]

While it is important to be humble and honest in concluding that science in the elementary classroom has changed little in recent years, it is more important to analyze why, in the hope that we can uncover more fruitful ways of helping teachers to implement new programs.

Apart from the fact that the whole notion of "teacher proofing" smacked of 1984 and treated intelligent educators as low-level technicians, these curricula were often developed in isolation from the realities of the classroom. They did not and could not take account of existing teacher characteristics, nor could they capitalize on local resources or individual pupil needs and interests.[5] Furthermore, the directions and guidelines as to how the curricula should be used, no matter how "simple" they had appeared to the curriculum developers, still erroneously assumed that the classroom teacher would share the positive attitudes, security, and familiarity with the subject matter, of their originators. As revealed by the Rand and N.S.F. studies, the weakest link in curriculum development during the 1960s was the process of implementation. Naivety was rampant: the adoption of a new program was equated with actual classroom implementation.[6] The required amount of in-service education deemed necessary was woefully insufficient, and in most cases not provided anyway. So it is not surprising that most curriculum documents ended up on the shelf gathering dust. It must be made clear that teachers should not bear the main burden of blame. Those who attempt to control what teachers do expected too much too quickly, without providing resources for teachers to develop the necessary skills to do the job.

Happily, another generation of change effort is now quietly pervading our schools, sometimes using the products of the curriculum reform movement, sometimes using second generation programs or more locally produced materials.[7] In any case, they are characterized by different expectations in terms of the level of complexity of the change, the speed of change, the degree of support available before and during implementation, and the degree of teacher involvement in the change process. The degree of implementation of new science curricula seems to depend to a very large extent on these factors,[8] and any schoolboard that neglects them during a curriculum revision may be wasting time, money, and effort in return for little change in classroom practices.

Recent plans for change have attempted to strengthen the weak link of the 60s; however, they have not gone far enough. Even if one assumes that the curriculum is appropriate, that materials are adequate, that teachers have sufficient familiarity with the content through in-service education, and that there are dynamic support and feedback mechanisms to meet teacher needs, actual implementation of an educational innovation can only occur at the classroom level, regardless of changes in administration, curriculum, or facilities and resources.[9] A clear delineation of a particular change at the classroom level would involve an accurate description both of current transactions and of the desired future pattern of transactions. The important focus of any implementation effort, however, must be the *process of transition* from one to the other.

The change from the traditional to the inquiry approach is quite radical and complex. It requires not only new or different skills, but changes in attitudes towards knowledge, learning, and children's behavior which are quite difficult for many teachers to make. Very few innovative projects have provided teachers with the gradual step-by-step procedure necessary for making these difficult changes, even if they wish to make them. We have failed to apply two eternally sound educational principles: (1) Start from where the learner is (in this case both teacher and pupil are learners) and (2) Provide for learning at the learner's pace, in increments that will encourage success.

A transitional curriculum

The aim of this paper, therefore, is to provide an illustration of the kinds of thinking, planning, and practical steps needed, *at the classroom level,* for a gradual implementation of an inquiry-oriented elementary science curriculum. It commences from the transactions one might find in a conventional classroom for science, and proceeds in a step-by-step fashion towards the much more complex roles and transactions of pupils, teacher, and materials found in an inquiry-oriented classroom.

This paper takes the view that whereas every curriculum innovation should include illustrative transitional curricula such as the one included here, there is no better guarantee of change than having teachers themselves develop plans specifically suited to their own classrooms. Implicit in this view is that each teacher should be given time and support to develop such a plan during in-service sessions with a curriculum consultant. The phases and steps illustrated in this paper represent the type of interim goals negotiated between consultant and teacher that can effect desired change.

Phase One: establishing two-way communication

The objective of this phase is to establish two-way verbal interaction between the teacher and children, and to encourage children to think.

1.1 Science using a text

The most traditional approach to the teaching of science consists of the teacher using the text to tell and recite portions of science knowledge to pupils who listen, read, write, and regurgitate remembered responses. Communication is mostly one-way, from the teacher to the students as a whole class.

1.2 The text and questions

The first step in moving towards open transactions is to introduce and establish two-way verbal communication. Without changing any materials or classroom set-up the teacher may introduce a questioning approach, which, after the usual style of presentation from the text, requires that the teacher ask a series of questions giving as little information as possible. The pupils, having been informed of their new role, are given time and are encouraged to respond and establish two-way communication. The proportion of questions may be gradually increased until a Socratic style has been arrived at.

Phase Two: eyes on

The objective of this phase is to change the focus from a text to real events and materials, but without the added task of pupils manipulating the materials.

2.1 Using a film loop or film

A suitable activity for this step is a film loop called "Ice Cubes" from Richard Suchman's *Inquiry Development Program.*[10] The film loop shows an ice cube floating in one container of liquid and sinking in another container of apparently the same liquid. Having shown this discrepant event, the teacher instructs the pupils to solve or explain it by asking the teacher only questions which may be answered by a "yes" or "no." Students ask individual questions and build their own explanations of the event. This high prestructuring of roles reduces teacher information-giving and encourages pupils in speculative thinking and questioning. They develop powers of observation and inference and general skills of inquiry, without the complications of having to conduct the experiment themselves. The dominant interaction here is two-way communication between students and teacher as in the previous step, but with the focus of a real event. There is more pupil initiative and less information-giving by the teacher.

2.2 A live demonstration

Now the teacher must begin to develop some personal manipulative skills. An activity suitable for this step is a demonstration of "Sink and Float" from the Elementary Science Study Curriculum,[11] where everyday materials are presented to the class so that they may predict whether the object will sink or float in a container of water. Several puzzles whicn can add to the arousal of children's curiosity may be included. A cork that will sink because it has metal embedded in it, or clay that floats since it has a hollow ball inside it, work well. The children then attempt to explain the behaviour of these objects.

In this activity the actual materials are present, but the teacher handles them on behalf of the students. As opposed to the previous step there is no stringent role structure here, although the teacher still refrains from giving information. The teacher provides materials, creates puzzling situations, demonstrates, questions, and makes manipulations suggested by the pupils, who observe, infer, identify the properties of objects, classify, question, and hypothesize. Here is where some interaction with peers may be encouraged. The main transaction though is still between the pupils and the teacher, but with real materials as a focus. So Phase Two has maintained the two-way communication of Phase One, but has provided eye contact with real materials as a focus for that interaction. Also in this phase the pupil has an opportunity to initiate discussion and to develop the intellectual processes of science. The teacher's verbal contribution decreases during Phase Two as the indirect role is gradually assumed.

Phase Three: hands on

The objective of this phase is to introduce pupils to the direct manipulation of materials.

3.1 Each child handles materials

Each pupil is given a battery, a bulb, and one wire, and is asked to find as many ways as possible to light the bulb using only those materials.[12] Having built up pupils' intellectual inquiry skills and weaned the teacher away from recitation, Phase Three places materials in pupils' hands. This point is usually the critical point in the classroom, for the teacher is probably short of materials, a situation which requires the children to work in groups. The excitement of having something to hold added to having to share it often leads to failures of self-control. Therefore, *at this stage,* it is essential to have enough material for *each* pupil, thus minimizing difficulties of pupil interaction. Simple materials and a simple task are further guarantees of success for this first material-centred activity.

The teacher role in this phase involves careful logistics. He or she carefully instructs pupils as to their task and how they should record what they do. When this is clearly understood by everyone, the teacher organizes the distribution of materials, and the pupils may begin their task. The pupils handle the materials, making decisions as to how they will arrange them in order to light the bulb. They observe and record what works and what does not. Having initiated the activity, which is usually self-sustaining, the teacher is free to circulate, questioning, responding to inquiries without giving information, diagnosing difficulties, extending learning, and providing technical language when appropriate. The teacher's role is to support the child's learning by making unobtrusive interventions into the child's work with materials. It does not consist of hanging around looking lost and doing nothing. The objective of this phase is to get children used to conducting inquiry using their own materials. Once that has been achieved the next phase may be attempted.

Phase Four: building group skills

The objective of Phase Four is to build group skills. The dysfunctional interaction of pupils who haven't been given a chance to develop group skills can very often ruin a teacher's attempt to change the classroom.

4.1 Pairs

The most appropriate activity for this step would be something emerging from some task where *each* individual pupil has been interacting with materials. In this case, one can build on an existing familiarity with the materials and type of task. It is logical therefore that we should select another Battery and Bulb activity from the Elementary Science Study for this step. After they have finished the task described in the previous phase, the pupils are asked to work in pairs in order to discover how many different ways they can light two bulbs using their combined materials. The pupils need each others' materials, and also each others' hands to assemble and hold various possible circuits. The teacher's role in this step is similar to that in 3.1, but emphasis is placed on developing the pupils' skills of working together, pointing out how they can help each other to solve the problem by sharing, cooperating, and discussing. The dominant interaction, therefore, is of pupils talking and working with each other, as well as with the materials.

4.2 Trios

Whereas the previous step used a natural approach to grouping, with relatively undefined roles, this step, in enlarging the group to three members, necessarily introduces the concept of division of labour and group roles. At the beginning of group work neither the children, who have not yet developed the skill of designing and ascribing roles, nor the traditional teacher, who is used to being the focus of attention, are easily able to author their roles. They need a supporting structure until these skills have been developed. One of several vehicles which provide highly prespecified roles but at the same time promote group interaction is the simulation or game. An activity appropriate for this step is a communications game using any set of blocks with varying attributes of size, shape, colour. This game emphasizes the skills of science.

Two identical mixed sets of blocks are given to each of two group members. One pupil, out of sight of the second pupil (use a screen or have the pair work back to back) builds a pattern with the blocks. Each time a block is added to the pattern the pupil describes the move as accurately as possible so that it can be duplicated by the partner. The third child observes and takes note of the proceedings, giving no verbal or non-verbal clues as to the accuracy of descriptions or moves. It is his or her role to take part in and add to the discussion of the similarities and differences in the two patterns after the game has been played for a while. This pupil is in a position to offer comments on properties of objects missed, inaccurate descriptions of moves, and incorrect listening. The teacher, in the meantime, supervises the playing of roles and aids with post-game discussions. After each game participants may change roles. This experience, then, permits *controlled* individual contributions to group activity while pupils learn to work together.

4.3 Quartets

When the group size is increased to four it is important to retain simple materials, tasks, and pupil roles. Creature Cards[13] is an activity which involves the pupils in classifying amusing figures using increasingly complex properties and attributes. One set of cards is given to each group of pupils, requiring them to share, discuss, and cooperate in solving the creature card problems. As opposed to the previous step, neither roles nor strategy are prespecified, but they are left to the groups to work out if necessary. The teacher's role here requires an increased supervision of group dynamics, with attention being paid to ensuring that *all* individuals participate in problem-solving. With the creature cards as a common focus the dominant interaction here is probably peer interaction in discussing, testing, and working out decisions.

4.4 Quartets of children with complex materials

The Mystery Powder[14] activity from the Elementary Science Study Curriculum involves the use of everyday powders from the kitchen. Children record the appearance and taste of each of several powders as well as the results of other "tests" involving water, vinegar, iodine, alcohol, and heat. They conduct these tests in order to build a matrix of properties of the powders, so that they may identify mystery powders which consist of mixtures of the original powders.

This activity is relatively complex, involving multiple materials, and requires the members of each group to decide on what role each should play. The teacher's role necessitates the carefully organized distribution of materials as well as the giving of clear, step-by-step written and oral instructions as to what is involved. As with previous activities the pupils are involved in manipulating, observing, inferring, classifying, comparing, contrasting, and recording. The teacher ensures that each pupil has a turn at each of several roles involved in the activity. After several sessions of mystery powders, pupils will have learned to work effectively in groups while conducting complex investigations, and will be ready for the next phase of this role transformation.

Phase Five: implementing pupil intentions

Previous phases have separately focused on encouraging thinking, flexible verbal interaction, changing the teacher role from lecturer to facilitator, gradually moving pupils into direct manipulation of materials, and building group skills. Phase Five focuses on a gradual increase in scale of participation by the pupil in making decisions about how and what to learn.

5.1 Children choose how to solve a given problem

This initial step of Phase Five provides pupils with a problem to solve with the aid of some basic materials. How they go about solving or investigating the problem is for small groups of pupils to discuss and decide. A task which would foster this type of decision-making goes as follows: Given paper, clay, metal foil, and other basic materials, who can make the best boat? The pupils organize small groups and cooperatively decide their own strategy and minor objectives for reaching the goal. What materials should be used and how? What shape or design should the boat take? How do we measure whose boat is the best? As in the previous phase the dominant interaction is of peers with each other and with the materials. The nature of this interaction now, however, gives more opportunity and time for making choices and decisions. The teacher, as before, provides materials, sets the initial task, and provides guidelines as to how pupils could approach their task. During the activity the teacher may be seen actively engaged with pupils in conducting investigations: trying things out with and for them, contributing ideas along with the pupils, and learning more not only about each child's way of learning but about the problem at hand as well.

5.2 Thematic approach: Children set their own task within a given theme

Having conducted several activities within which children have, in conjunction with the teacher, developed the skills to specify short term objectives and strategies, a thematic approach may be used. Much broader in scope than the specific task set for the pupils in step 5.1, this approach allows individual pupils to select their own specific task within a general theme. The teacher might have chosen the theme of "your bicycle" as a project. This topic might be of current interest to the class as well as being important to a concern for road safety. The teacher may introduce the theme to the children by way of a curriculum web, which presents possible investigations, and which they might expand before selecting their own mini-themes. Children who are interested in similar things have a natural reason for working together. As it communicates its findings, each group contributes to the knowledge base of the whole class, besides developing investigative, communicative, and social skills. In this step the teacher sets the general theme, maps the terrain of possibilities,[15] organizes and coordinates pupil groups and tasks, and assists the pupils as needed. The pupils select or create tasks based on their interests, group themselves accordingly, and plan strategy for achieving their objectives. The task complexity, degree of prestructuring, interaction with materials, group size, and other factors are therefore individualized and flexible. This step is an ideal time to integrate science (if the integration has not occurred already) with other curriculum areas.

5.3 Decentralized thematic approach

At this step pupils, having developed sufficient independence and personal skills, are able to initiate their own broad themes or projects. Pupils with similar interests may work together planning out strategies and activities. The teacher acts as a resource person and advisor for these individualized themes. She or he is still responsible, however, for the child's education, and will sometimes redirect children in their personal pursuits.

Summary

In devising a transitional curriculum suited to a particular classroom, the teacher should first define the overall change in terms of existing and desired roles, materials, and activities. Secondly, the teacher should break this overall change into gross phases similar to those illustrated in this article. Within each phase, several small steps should be planned that would facilitate the successful learning of new pupil and teacher roles and transactions, using content appropriate to the new curriculum.

The crucial objective of this exercise is to make only a small intended change each time. Several of these small steps will accrue to create a more significant change, as the transitional curriculum builds the necessary pupil and teacher skills. A new step or phase is not attempted until the role changes of the previous step have been learned by as many replications as are required for mastery.

In advocating the use of transitional curricula, this paper has taken the position that successful implementation of elementary school science curricula must be reflected in the classroom, whose main actors are teachers and children. Therefore, as the studies which confirm the failure of the curriculum reform movement[16] illustrate, local efforts which consider the classroom as the main focus and arena of change efforts will prove the more fruitful.

Assuming an elementary science curriculum which is suited to the needs of the children and the locale, complete with adequate materials and in-service training, the teacher who wishes to change is still faced with doing it in the classroom. This is the practical nub, and it is the nemesis of all theoretical models for change, especially as applied to the radical change required by inquiry-oriented elementary school science.

The idea of the transitional curriculum, whose objectives focus not on curriculum content but on changing roles and transactions in a gradual way, has been illustrated here in the hope that teachers will be given the time and resources to develop their own plans for change. If they are to be involved in any aspect of curriculum development at all, it is obvious that they must be involved in developing plans for changes in their own classrooms. Perhaps then we can avoid the classic change symptom (and this is not meant to be pejorative to teachers) which sounds as follows: "It won't work in my classroom. It's not practical. I tried it *once* and there was chaos!"

NOTES

1. Decker F. Walker and Jon Schaffarzak, "Comparing Curricula," *Review of Educational Research,* Vol. 44, No. 1 (Winter 1974), pp. 83-111.
2. R. L. Butt and M. F. Wideen, "Division III Science: Some Initial Findings of an Evaluative Study," *Saskatchewan Journal of Educational Research and Development,* Vol. 3, No. 2 (Spring 1973), pp. 4-13; R. L. Butt and M. F. Wideen, "The Development, Validation and Use of an Arbitrary Implementation Scale as a Basis for *Ex Post Facto* Curriculum Evaluation." A paper presented at A.E.R.A., Chicago, April 1974.
3. W. W. Charters and J. Jones, "On the Risk of Appraising Non-Events in Program Evaluation," *Educational Researcher,* Vol. 11, No. 2 (1973).
4. A large series of studies conducted under the auspices of the National Science Foundation in the United States concluded that teachers of science, mathematics and social studies seldom use the inquiry approach. See the *Report of the 1977 National Survey of Science, Mathematics and Social Studies Education, Case Studies in Science Education,* Volumes I and II. All available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The Rand studies also confirm the same opinion; their findings are published (eight volumes) in a series called "Federal Program Supporting Educational Change". They may be obtained from Rand Publications, 1700 Main Street, Santa Monica, California 90406.
5. For a Canadian example which does have a grass roots flavour see a paper by Gary Anderson, Ann E. Brimer, and Muriel Cooper, "Developing Curriculum for Canadian Schools: What We Have Learned from the Atlantic Salmon," *Interchange,* Vol. 8, No. 4 (1977-78), pp. 16-31.
6. Kenneth A. Tye and Barbara T. Bonham, "The Realities of Curriculum Change: Into an Era of Uncertainty," *Educational Leadership,* Vol. 36, No. 1 (October 1978), p. 36.
7. Anderson et al., *op. cit.*
8. Butt and Wideen., *op. cit.;* M. Fullan and A. Pomfret, "Research on Curriculum and Instruction Implementation," *Review of Educational Research,* Vol. 47, No. 1 (Winter 1977) pp. 335-397.

9. Charters and Jones, *op. cit.*

10. J. R. Suchman, *Inquiry Development Program* (Chicago: S.R.A., 1966).

11. Elementary Science Study, *Teachers' Guide for: Sink and Float* (Toronto: McGraw Hill, 1968), pp. 11-13.

12. Elementary Science Study, *Teachers' Guide for: Batteries and Bulbs* (Toronto: McGraw Hill, 1968), pp. 9-15.

13. Elementary Science Study, *Teachers' Guide for: Attitude, Games and Problems* (Toronto: McGraw Hill, 1968), pp. 74-77.

14. Elementary Science Study, *Teachers' Guide for: Mystery Powders* (Toronto: McGraw Hill, 1968).

15. J. D. Hassett and A. Weisberg, *Open Education: Alternatives Within Our Tradition* (New Jersey: Prentice Hall, 1972), pp. 77-78.

16. See note 4.