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Constructivism, interactive science teaching, cris, and "science for all": Gapsin the new orthodoxy

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ABSTRACT
Since the developments of the Learning in Science Project (LISP) at Waikato University in the 1980s, teachers in both primary and secondary teaching concerned with science education have become aware that something "important" is coming from Waikato. There is a great deal of talk about "interactive science teaching", "generative learning", and "constructivism", and even "LISP teaching" or "Waikato Science" as I have heard one teacher describe it. These ideas have been often tied to the notion of "science for all". However the theoretical base underlying some of these latest trends in science education which became manifest in the F1-5 Curriculum Review in Science (CRIS) started in 1985, has not been really discussed in a public forum. Much of the comment and criticism of both CRIS and the syllabus has tended to be directed at the perceived effects of that syllabus "as a curriculum to be delivered" rather than at the theoretical base underlying it. This criticism has helped the new Minister of Education to leave the CRIS project sitting on the table while yet another group attempt to repeat the same process. Yet this theoretical base has become part of the 'taken-for-granted', the commonsense of science education: it is the new orthodoxy. As such there needs to be a deeper debate. I intend to explore the history and rationale for this new orthodoxy of science education. This will be discussed particularly in relation to the idea of "science for all" which underlies some of the current debate in science education.

Introduction

Since the developments of the Learning in Science Project (LISP) at Waikato University in the 1980s, teachers in both primary and secondary teaching concerned with science education have become aware that something "important" is coming from Waikato. There is a great deal of talk about "interactive science teaching", "generative learning", and "constructivism", and even "LISP teaching" or "Waikato Science" as I have heard one teacher describe it. These ideas have been often tied to the notion of "science for all". However the theoretical base underlying some of these latest trends in science education which became manifest in the F1-5 Curriculum Review in Science (CRIS) started in 1985, has not been really discussed in a public forum. Much of the comment and criticism of both CRIS and the syllabus has tended to be directed at the perceived effects of that syllabus "as a curriculum to be delivered" rather than at the theoretical base underlying it. This criticism has helped the new Minister of Education to leave the CRIS project sitting on the table while yet another group attempt to repeat the same process.[1] Yet this theoretical base has become part of the 'taken-for-granted', the commonsense of science education: it is the new orthodoxy. As such there needs to be a deeper debate. I intend to explore the history and rationale for this new orthodoxy of science education. This will be discussed particularly in relation to the idea of "science for all" which underlies some of the current debate in science education.

The most public view of these notions of science education, which emerged from the Centre for Science and Mathematics Education Research (SMER) at the University of Waikato, can be garnered from the CRIS documents. A particularly important source of these views are those expressed in the publications of Dr. B. Bell who as Education Officer, Curriculum, in the Department of Education, was specifically responsible for the review. Dr Bell continued the completion of this review under contract, when she left the Ministry of Education to take up a position at the University of Waikato. As mentioned earlier, at the insistence of the new Minister of Science and Technology, a repeat performance is about to take place, which may share the same theoretical base of the new common-sense view of science education - "interactive science".

The Curriculum Review in Science (CRIS): the key ideas

The CRIS was set up by the Department of Education in 1985 to review, revise the curriculum, and write a syllabus for Forms 1-5 Science. The Review promoted a series of aims for science education which became its taken-for-granted base. Essentially, the review aimed to develop a science curriculum that incorporated the following notions:

1. The constructivist psychology, generative learning and interactive teaching that have emerged from the Learning in Science Projects of Waikato University:

    > developing teaching and learning activities to help students construct understandings about their biological, physical and technological worlds that are meaningful and useful to them (Bell, 1987).

2. The social equity concerns of the 1980s. These had been made official through the recommendation of The Curriculum Review, (1987) that education be non-racist and nonsexist. This was interpreted in the CRIS as forming the basis of the particular New Zealand variety of "science for all":

    > developing teaching and learning activities and curriculum materials that help more students feel part of and a sense of belonging to science, by using the experiences, interests and concerns of girls, Maori and Polynesian students in classrooms as well as those of boys (Bell, 1987).

3. A view of science as a useful, human activity:

    > developing a science curriculum that promotes a view of science as a human activity (Bell, 1987).

4. Putting the learner into the main focus of the curriculum, so they become self-motivated for their own learning - a child-centred curriculum:

    > a curriculum that encourages students to go on asking questions about their world and to help them seek answers to those questions, hence helping them to be more responsible for their own learning (Bell, 1987).

These four notions will be discussed, unravelled, and deconstructed in an attempt to trace them back to their origins in relation to the idea of "science for all". They will be examined under the following four headings:

1. Constructivist science, generative learning and interactive teaching;
2. The Labour Government, the Curriculum Review and "Science for all";
3. Science as a useful human activity; and
4. The Child-centred curriculum.

Constructivist science, generative learning and interactive teaching

Constructivist science

The Learning in Science project was set up in 1979 as a funded project of the Department of Education. Using two similar techniques, 'interview about instances' and 'interview about events', the team investigated the ideas children have in relation to various concepts categorised as 'scientist's ideas' (Osborne and Freyberg, 1985). Using a framework that derives from Kelly's (1955) "Personal Construct Theory", of "Man as Scientist," the team found empirical data to support the following conclusions:

1. That from a young age, children develop meanings for many words used in science teaching, and views of the world which relate to concepts taught in science;
2. That children's ideas are usually strongly held, and are often significantly different from the views of scientists; and
3. That these ideas are sensible and coherent views from a child's point of view, and they can often remain uninfluenced or be influenced in unanticipated ways by science teaching (Osborne and Freyberg, 1985).

Kelly's theory of personality, Personal Construct Theory, is idiographic, stressing the uniqueness of the individual and attempting to provide a psychology about the total personality. It is philosophically a phenomenological view (Gross, 1987:648).

> Man looks at his world through transparent patterns or templates which he creates and then attempts to fit over the realities of which the world is composed. The fit is not. always very good. Yet without such patterns the world appears to be such an undifferentiated homogeneity that man is unable to make sense of it (Kelly, 1955).

These constructs, created to enable 'man' "to make sense of the world", are not fixed. The person, as 'scientist' in Kelly's terms, is constantly engaged in testing, checking, modifying and revising the unique set of constructs by which they make sense of the world - as he says scientists do. The better our personal constructs, the better will be our control over our own personal world. Under this framework meaning is essentially an individual process: "making sense of the world" by forming personal theories or hypotheses that enable prediction. Each time we act, we are putting our hypothesis to the test, and in this sense behaviour is an experiment. This use of the notion of constructs has been generalised to the notion of 'prior knowledge', or those ideas and concepts (constructs) which the student brings to bear on any new situation.

This notion bears some deal of superficial similarity to Dewey's concept of 'experience' (Dewey, 1916, 1925). For Dewey though, meaning is socially established through the interaction of the self and society in a dialectical relationship which can be termed 'experience'. This experience is in continuous relationship with the environment, which is being modified as a result of the experience:

> Education: it is that reconstruction or reorganisation of experience which adds to the meaning of experience and which increases ability to direct the course of subsequent experience (Dewey, 1916:76).

Whereas Dewey's pragmatic philosophy is essentially social, personal construct theory or constructivism is essentially individual. Within the latter each person develops their own constructs to interpret the world. This has the effect of portraying meaning as totally individually determined. Meaning is personal. This effectively dissolves science into an individual search for meaning. Pure constructivism however fails to acknowledge the socially determined nature of science except in the sense that it is a series of individual constructions:

> Knowledge is the personal construction of an individual and does not exist to be externally transmitted (Bell, 1985).

There is a logical difficulty in using Kelly to underpin science education. Kelly's constructivist theory extrapolates from "scientific method" to a psychology of individual learning. The step that later constructivists have made is then to reapply this theory back from individual psychology to science education itself, and hence to science. The tautological reasoning has become mystified though as a result of the empiricism underlying the LISP work itself. The project data proved the existence of that which is held to be there. Constructivist research proves the existence of constructs.

Despite its inherent weaknesses, constructivism has developed an enthusiastic following in New Zealand science education circles.[2] It is on this constructivist base that the LISP team developed their models of "generative learning and interactive teaching". These models were of practical importance to teachers in explaining their own teaching. However, supported by the mystique and protective belt (qua Lakatos). of indigenous empirical research, and by a succession of visiting overseas "experts" (notably Driver, Gilbert, Fensham and Claxton), the tentative nature of the core theory had become somewhat lost.

Generative learning and interactive teaching

The "generative learning" model of teaching (Cosgrove and Osborne, 1985), was developed by combining a number of factors and applying them to the learning of science (Osborne and Wittrock, 1983). The factors they used were derived mainly from cognitive psychology:

- Wittrock's generative learning model of cognitive psychology, whereby learners actively construct or generate meaning through sensory input combining with prior understanding;
- Ausubel's initial notion of subsumers; and
- views from the language and learning field, such as those of Barnes (1969, 1976).

The resulting model uses organised learning activities to achieve four major goals, namely:

1. To determine the student's views or what has been called their "prior knowledge";
2. To focus, or motivate, the student to consider their own view;
3. To challenge the students to consider the views of other students and the scientist's (sic, Biddulph and Osborne 1984: 18) view, and to take this on board by making it their own; and
4. To apply the concept in solving practical problems.

This sequence has been generalised and designated "interactive teaching", a classroom approach that has also been advocated in social studies, health, language and, more recently, mathematics teaching. In essence the teacher ascertains the views of the students then interaction or discussion between the students and the teacher determines the course of an investigation or the production of meaning. The aim of the investigation and the learning is to help the students make "sense of their world" (Biddulph and Osborne, 1984). The student determines the questions to be investigated and the teacher acts as a motivator, diagnostician, guide, innovator, experimenter and researcher, in accordance with the needs of each individual child (Osborne and Freyberg, 1985). The pedagogical requirements for each child will somehow emerge from the task itself. The investigation ends when the child has made "sense of the world" in a way that is satisfactory to her.[3]

The Labour Government, Curriculum Review, and "Science for all

The Curriculum Review was set up by the incoming Labour Government with the assistance of the New Zealand Post-Primary Teachers' Association in 1984 to involve as wide a number of people as possible in the review of the curriculum. {This review itself was a political response to the views of Wellington, the earlier Minister, who had been opposed to the increasing influence of the teachers' unions particularly, as he saw it, and the increasing push for teacher control of the curriculum dominated by feminists: Wellington, 1985). The aim of the Curriculum Review was to involve the general population in the process of education, and collect those views as the basis of official decision making. A number of booklets were circulated through all of the educational institutions from pre-school to tertiary levels, to reach parents, teachers, students and the community together with a request to express views on the future direction of schools. The 21,500 responses were collated as a summary of views entitled the Curriculum Review using selections of these public responses as illustrations. The Curriculum Review produced a broad report which gave official support to education for equity, within a child-centered, holistic and relevant curriculum.

The importance of the Curriculum Review to the CRIS is noted by Bell (1987) in the following statements:

1. It is the first major education report that promotes the ideas of a non-racist and non- sexist curriculum for all New Zealand students;
2. It is the first major education report that promotes the recognition of the Maori people as the tangata whenua (the people of the land);
3. It acknowledges the place of the learner at the centre of schooling and the curriculum. The curriculum must be seen by the learner as whole, enabling, useful, and enjoyable; and
4. It has used the wider definition of 'curriculum', that is "all the activities, events and experiences that take place in the school's learning programme".

Throughout the Curriculum Review there is a consistent linking of the issues of equity for women and Maori with education. This is the standard position of both progressive educationalists and liberal feminism. Much of the feminist concern with equity is related to imported debate (Bunkle, 1979). It Is based on liberalism, the ideas of John Locke, and a concern with individual rights and fairness (see Dann, 1987). The notion that the structuring of society is integral to the nature of that society, becomes conflated into the demands for fairness. The two issues which cause difficulties for feminist theory, as they also do for liberal theory, are class and race. Class as an issue is easily disposed of, liberal feminists just ignore it! New Zealand does not have the visible class divisions of Britain, so that class as an organising principle becomes invisible. Race or ethnicity, however, is a more difficult question New Zealand has an indigenous ethnic minority which, since the 1970s, has been able to offer a political challenge to the dominant Pakeha population. As Christine Dann (1987) explains in her analysis of the history of the Women's Movement, feminism in New Zealand, under pressure from Maori women, has accepted anti-racism as part of its agenda, as a matter of fairness. This was a consequence of the movement's liberalism, although the interpretation is generally inherently individualist.

To return to the discussion of the science curriculum, in CRIS these equity matters were related to the discourse of "Science for All". "Science for All" was an idea popularised in New Zealand science education through Peter Fensham's (1987) article. Fensham was critical of the accessibility of science to the general population, advocating a science curriculum to serve the 80% presently excluded, rather than the 20% currently served. This would need to be a science education for general education rather than the previously vocationally-directed curriculum which aimed at teaching students to "discover" like scientists.

Other matters as well became incorporated in the 'Science for all' discourse as it developed in New Zealand. There was a concern about the alienation of the general population from science, caused by the "image of science as an objective, analytical and rational activity" (CRIS, 86: 2). The 1986 CRIS discussion papers which initiated the review raised questions about the relationship between science education and girls, as well as ideas about multicultural science education. The ideas in Fensham's (1987) article became merged with those ideas in the Curriculum Review report:

> ... in the report Curriculum Review the fifteen principles advocate learning, including learning in science, that is useful, relevant, enabling, accessible, enjoyable, successful and integrated for all students, including:
>
> girls as well as boys
>
> Maori, Polynesian as well as European students
>
> those seeking and not seeking future employment in science and technology,
>
> all students in Form 5 (age 15)
>
> students with different experiences and aspirations,
>
> students with different abilities and skills (Bell, 1987: 9) (my emphasis).

"Science for all" therefore was science that was useful to everyone. To this end the CRIS emphasised the idea of science in the world of the student, which was seen as different from the science in the world of the scientist (Bell, 1988a: 21). So that "rather than taking students to the world of the scientist" which was seen as elitist, rational and objective, it was seen as more appropriate to "highlight the science in the world of the student to help them better understand the science in their own lives. (Ibid.)"

What was being advocated is a science education for a number of purposes, one that recognises a plurality of views, and shifts to science through its various applications, rather than the more traditional view of moving from science to the application:

> The way in to learning scientific concepts and skills for many girls may be through investigating human problems and the way science and technology influence the lives of people (Bell, 1988b).

Science as a useful human activity

The third element in the CRIS rationale is the notion of science as a useful, human activity.[4] In a paper given to SciCon, the NZ science teachers conference in 1986, Bell outlines her arguments for science as a human activity as follows:

- Scientific understandings (models, interpretations, theories) are constructions of the human mind in an effort to make sense of phenomena .
- Science is an activity done by a person or usually by groups of people. Working co-operatively and in collaboration with other people is a part of science for it involves communication with others.
- Science influences the lives of people, for example antibiotics and nuclear weapons.
- The ideas, beliefs, values and culture of scientists, to varying degrees influence scientific activities and understandings, for example current research on reproductive technology and weaponry (Bell, 1986: 7).

These descriptions are very different from the objective, rational system that has been called science (Chalmers, 1976). Indeed, Bell (1988b) believed a major criticism of science education was that

> Science has been portrayed as a discipline promoting objective, rational and analytical behaviour (Bell, 1988b: 59).

The constructivist views, promoted by Bell (through CRIS), if it were not for their phenomenological individualist base, could be described as a "consensus approach", wherein the beliefs or "constructions", of individual scientists are combined to form the ideas of the scientific community. The definition of science used by the constructivists reflects this confusion between individualism and social determinism: "scientific thinking .. is a human invention which involves using language to paint the perceptual world ... we construct our own realities (Munby, 1982: 21)".[5]

Thus, the "forces" involved when a ball is hit are the personal constructions of individual physicists, who have reached some sort of consensus on how to describe, explain or measure the "hidden thing" that affects the momentum of a golf ball. They have made "sense" of the thing, "from their prior knowledge": "our existing ideas and experiences influence what we attend to in our environment and also determine what understandings we construct" (Bell, 1988b: 59).

Such a view of science can be described as relativism (Chalmers, 1976: 99).[6] Within this framework one view is as good as another. When extended to science education this would mean that the ideas children bring to the classroom are just as valid as those of the scientists. The aim of science education becomes one of exploring individual meaning - of children being able to "make sense of their world":

> ... developing teaching and learning activities to help students construct understandings about their biological, physical, and technological worlds that are meaningful and useful to them (Bell, 1987).

While this may be useful as a model of science education, as a model of science it is fraught with difficulties and inadequacies for those who wish to retain the rationality and objectivity of natural science.[7] We have a process of explaining science and learning science which proceed from fundamentally contradictory positions. Science as a particular discourse can be said to be a socially shared and developed discourse. Constructivism however is based on the individual meaning construction. There is no way in this for the collective view to emerge. The 'Social' in this framework appears as the sum of the various individuals, while the relationship with reality itself is not even mentioned.

However, these objections are arguments from outside the developing science education discourse, outside the developing orthodoxy. The discourse of "Science for all" - at least as it was developing in New Zealand - defined 'ideas from the world of the scientist' as "elitist", the discourse of liberal feminism underlying much of the Curriculum Review defines objectivity as "male", and the discourse of constructivism defines knowledge as "personal". Unfortunately the distinction between science and science education becomes blurred. This difficulty is compounded by those involved in science who hold an "absorptionist" rather than constructivist view of learning.[8] A false dichotomy is set up between university (real, elitist) science and school (applied, relevant) science.

The second part of the notion of "science as a useful activity" relates to the uses of science. Learning in science ought to be seen by students as useful in and related to their world (Bell, 1988).

But contrary to the myth promoted by university scientists, the CRIS was not advocating a different science as such. Instead it advocated a differently focused science education, one which focused on the applications first rather than on the science. This is seen as a science education that relates to the human contexts of the students (Bell, 1988a) in order "to allow access to the decision making processes", and yet as well to "increase the career opportunities for those traditionally excluded from science" (Bell, 1988b: 153). There are the aims of scientific literacy for all and existing vocational requirements intertwined in this notion of useful science. The contradictions involving technocratic rationality are not addressed.

Throughout the CRIS documents, science is seen as relevant, that is science is instrumental knowledge with a changing notion of "useful". This raises the question of usefulness. To whom is it useful? In this case, it seems students, or to be more specific particular groups of students with different ideas. But for what? Is it vocational, a way of solving problems, or useful as entry into a particular powerful discourse? All of these meanings are possible. Usefulness immediately raises questions of human interest. And the definition of usefulness therefore moves science education firmly into the political arena. However, in this conception of science education, there is no notion that the knowledge of science might be important in its own right, for knowledge's sake.

A Child-centred Curriculum

The three elements of constructivism, social concerns and 'science as human activity' are linked in the CRIS approach within the overall goal of developing a "child-centred curriculum." Already, the New Zealand primary school education is dominated by the "child-centred approach". Liberal educational theory is underpinned by the concepts of developmental psychology (Henriques et. al., 1984), and a "child-centred, activity-based, developmental curriculum catering for individual differences" is the dominant discourse in primary educational circles. Implicit in this is the view of the child as containing some sort of essence which determines their own rate of development and learning. This essence underpins learning and the child should be able to proceed at their own pace.

Much of the early work of the LISP team at Waikato developed from their Department of Education funded project focused on primary education - Learning in Science Project (Primary). This primary school focus was developed into the "interactive approach." The CRIS and other current developments such as the newly-established teacher development contracts, can be interpreted as an attempt to extend this child-centered ideology into the secondary school science curriculum. This 'child-centred, activity - based learning' with the particular inclusion of issues of ethnicity and gender, has been called modern progressivism (Levett et. al., 1989). But the individualism underlying constructivism mediates against any notion of social determination. This naturally causes difficulty for science education because the body of knowledge is part of the nature of the discipline. It is not some easily invented construct.

CRIS and "Science for All" - questions which need to be raised

The CRIS process was premised on the notion of "science [education as general education] for all". This is a very important goal and one which is ascribed to by many teachers of science as well as the general population. It is also, interestingly, being presented as part of the National Government's Achievement Initiative. However there are a number of problems in this idea which are caught within the constructivist framework that the new orthodoxy in science education has established. In particular, difficulties emerge for working class students, for Maori students, and for expressed Maori aspirations.

First, there is a problem with the way constructivists frame the debate phenomenologically, in terms of a conflict between the world of the student in opposition to the world of the scientist. This dichotomy is not shared by other philosophers of science. Although there is a constantly recurring debate over the demarcation between science and other ways of knowing, science was not something that just came out of the "world of the scientists". It includes the process of particular investigations used to gain knowledge, bodies of theory and criteria of judgment. In Althusser's (1969, 1971) view, science is a set of particular social practices with particular historical development. The aim of science education must be for students to gain understanding of and access to these practices of science. A critical understanding of the natural sciences is different from the rejection of them. Constructivism is a psychological model. It does not address the philosophical and social difficulties which surround the discourse of science. These are important for a critical and effective science education.

The constructivist perspective sees science as the individual negotiation of meanings, the acceptance of a meaning being determined by the usefulness of a concept. This brings up questions of usefulness.

Who determines what is useful - individual scientists? No, that would be from the world of the scientists, which has already been re-defined as elitist. Children? teachers? or the Maori community? Possibly? Usefulness is such a value-laden term that unless the interest is made clear, many concepts may be restricted to the level of the commonsense, or the level of the practical. Some of the concepts in modern science are not in the slightest way useful to students in themselves. They are highly theoretical entities of explanation where their usefulness and their exciting potential comes from their disjunction from commonsense (Bachelard, 1969; Tiles, 1984). To create a new slogan "Science is not commonsense". Many of these notions are the blocks on which other notions develop, and have been used, in Bernstein's (1971) view, to restrict access to the power and knowledge of science to only those who have been initiated into the discipline.

Secondly, the constructivist position sets itself-in opposition to 'big ideas' science where the content of the curriculum was chosen for its importance in developing the "collection code" of the academic discipline of science (c.f. Bernstein 1971). What was, and still is, at issue for many science teachers is the remoteness of much of this 'big science' content to the immediate lives of their students. This concern has been picked up in CRIS and was coupled with the desire to bring female and Maori students into the rubric of science by making it relevant to them. However the method of increasing the relevance of science to these groups appears to be by counterposing the objective, rational study of the physical world with the study of science as human activity:

> Science is a human activity.
>
> We are all scientists to some extent. We investigate the kinds of fish in a stream: invent the idea of energy: hypothesise about toffee not setting: ponder on the question of what makes a rainbow: write and talk about whether to use nuclear power. Science is part of our daily lives ...
>
> Science is about people exploring and investigating their biological, physical and technological worlds, and making sense of them in logical and creative ways (Form 1-5 Syllabus for Schools, Draft May, 1990. Section 2, M.E., 1990).

Unfortunately the positivist equation whereby science is the pinnacle of knowledge has been flipped so we are getting close to the position that all knowledge is science. This is a more dubious claim and potentially very dangerous to those outside the current discourse of science itself. There are different ways of knowing about the examples quoted above, some of which may or may not be science. For example, hypothesising about toffee not setting could give rise to an number of responses ranging from the temperature was wrong or the ingredients were bad through to the bad spirits got at it, I wasn't feeling well, my little brother put his finger in it, or it always happens when I try to make toffee. Pondering on what makes a rainbow can likewise give rise to many answers such as God made the rainbow, it's a reflection of colours on the ground, the sun was shining through the clouds, or the gold at the end is shining up.

Learning about science does not necessarily teach children how to do science any more than learning about art is the same as doing art. It depends on a number of philosophical and methodological questions. Tossing a ball around does not in itself constitute playing netball. There are particular practices in netball, some of which are basic and mark the differences between netball, basketball volleyball or league. Unless the nature, process and the limits of science are also clearly elaborated we are in danger of losing sight of the discipline itself. This danger is especially true for those groups who are currently outside the discourse ... The opposition to positivism needs a strong assertion that natural science has very definite limits to what it can or should know about, and a resistance to spurious claims in areas of ideological struggle. But the opposition to positivism must be also coupled with an understanding of the strengths of science. As such there needs to be a stronger and more critical science education.

What the constructivists' opposition to 'big science' also has ignored is the structural role of science education. In Bernstein's (1971) and Young's (1971) analyses this 'big science' serves as a 'gate keeping mechanism'. That is the abstract nature of much of the content, and its fragmentation into steps of knowledge, is part of its function as a credentialling mechanism. Without addressing these credentialling structures, the notion of "science for all" becomes somewhat of a sham. The political and economic functions of science that are maintained through the examination structures are in contradiction to the desire for science education where all should have an understanding of science for psychological, social and cultural reasons, as well as for its vocational and instrumental benefits (c.f. Fensham, 1987).

But are these structural constraints changing? Implicit in the F 1-5 CRIS with its emphasis on the applications approach is a goal of reuniting the mental and the manual, of reasserting the importance of practice, of learning through "hands-on science". There is a difficulty in attempting through the vehicle of science education to close a separation which is at the base of the social division of labour. This division is economic with a very real effect on the position of the working class, the majority of whom are Maori or Pacific Islander. Making science education more practically or technologically oriented does not solve a difficulty which is bound up in the very organisation of society. It merely changes science education from a predominantly theoretical subject to a more practical one. Its actual function may be as a way for middle-class teachers to teach working class children (whether these be Maori or Pakeha) how to be the new working class, by stressing the practical at the expense of the theoretical. The New Zealand labour market may require some semi-skilled workers with a positive orientation to technology, but it does not really seem to require more scientists if the rise in the importance of commerce in the university is any guide, not withstanding demands by politicians. It could be argued that the effect of the changes in science education obscure the changing nature of capitalist political economy, and yet dissolve the theoretical skills with which to understand it. Is this the post-modernist science education?

As teachers grapple with the changing contradictions of their own roles, the underlying implications of the "modern ideas" promoted through the agency of official bodies and experts need to be available for the full, informed perusal and debate by teachers. Curriculum has been said to be "selections from the culture" (Lawton, 1983). What is selected, why it is selected, and who selects it, are matters of politics.

The development of an interactive form of science education may be a positive addition to the pedagogical repertoire of science teachers. It moves the notion of curriculum from a package to be delivered to a process of teachers developing children's understanding. It therefore increases the professional decision-making of teachers. However one needs to view with suspicion anything that is advanced as the answer to the complexities involved in science education. As most of these complexities are essentially social and, dare I say it, political, the individualist psychological base of constructivism does not offer a real solution to the difficulties in science education. The political answers for science will have to come from outside education not through it.

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Notes

1. There is currently a group of teachers trying to assemble a series of measurable outcomes for the Minister of Education's Achievement Initiative using this CRIS syllabus as a base. However at the request of Upton, Minister of Science and Technology, a Ministerial Review of Science and Technology Education was set up by the Ministry of Science and Technology in May 1990 to report back in November.
2. The enthusiastic support also generated funding support for the projects.
3. The enormous range of roles which the teacher has to play for all of her thirty children requires a great deal of skill and reflective understanding of science itself.
4. Some of the original drafts of the aims of this review related to "humanist science", a science which stresses and values the importance of humanity, but the terminology used later in CRIS referred to science as a human activity.
5. This definition and its deletions, is taken from Millar and Driver (1987) which argues against process science or what we in New Zealand call enquiry science, in favour of a constructivist approach.

6. Karl Popper has labelled a similar position 'psychologism' basing scientific knowledge on a set of statements which is guaranteed by private experiences. He labelled the philosophers who used subjective experiences - Descartes, Locke, Berkeley, Hume and Kant - as belief philosophers.
7. Bachelard (1969), the French philosopher of science, circumvents the difficulty of relativism with a notion of science as an historically and socially constructed discursive practice, discontinuous (in epistemological rupture) with commonsense. In a very strong sense science is not common sense. For Bachelard science is a structural discourse. (For a rationalist assessment of Bachelard's notion of science see Tiles, 1984).
8. A term applied to those who imply that human minds are like sponges and absorb the knowledge that is "transmitted" to them. Teaching in this model therefore becomes telling. It is a theory of pedagogy which underpins university science education.

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