

Gender issues and constructivism: Problems of theory

Johanne McComish

ABSTRACT

What are the gender issues for constructivist approaches to science education? Constructivist work on girls and science has ensured that gender issues now have a place in the national curriculum, and in the thinking of most science teachers. In this paper, I acknowledge that achievement, and take that as a starting point to explore further steps. It seems to me that the next steps taken should be theoretical. In this paper, I raise issues for future development under five general headings. These are: the nature of science; the purposes of education; the nature of individuals; how students learn; and the role of teachers. These issues are discussed in the second part of the paper. First I will define constructivism, and explain how gender issues are linked with theoretical problems within it.

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In this paper, I raise issues for future development under five general headings. These are:

- the nature of science;
- the purposes of education;
- the nature of individuals;
- how students learn; and
- the role of teachers.

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Constructivism

For the purposes of this paper, I define constructivism on the basis of the following three points. Firstly, this paper focuses on New Zealand science education. The development of constructivism in this country has been done at Waikato University, by the Centre for Science, Mathematics and Technology Education Research, and its predecessors - principally through the work of the *Learning in Science Projects* (LISP). The Centre has worked as part of a major mainstream international

movement in science education, particularly in association with constructivist research in England and Australia.

Secondly, constructivism is basically a theory of learning, which has branched out to some extent into the practice and theory of teaching, and into curriculum and the theory of science, to a lesser extent, with the intention of developing all of these into an over-all view of science education (Bell, 1991, 1993b).

Thirdly, I take the following three texts as setting out the basis of constructivist approaches to the learning of science. The first is the article entitled *The generative learning model and its implications for science education* (Osborne and Wittrock, 1985). The second is a 1991 collection of papers entitled *Learning in Science viewed as a Personal Construction: An Australasian Perspective* (Northfield and Symington, 1991), which contained amongst others an important paper by White outlining the development of constructivism by Australian and New Zealand researchers, and setting out in summary sixteen principles of personal construction of *interpretations, conceptions* and *beliefs*. The third text is *Children's Science, Constructivism and Learning in Science* (Bell, 1993a). In addition to Bell's new writing covering four central topics in constructivism (views of learning, children's science, a constructivist view of learning, and teaching for conceptual change), this book also contains important constructivist articles from 1981, 1985, 1989, and 1991.

Background

The rise and fall of constructivism (Solomon, 1994) describes the spread and influence of constructivism in science education over the last sixteen years. Solomon comments on the real contributions constructivism has made to science education, but also on the "cracks" (as she puts it) that have been appearing in various constructivist hypotheses about learning, and in classroom applications of these. She notes that critiques of aspects of constructivism have started to appear, and that constructivism seems to be failing to generate further stimulating ideas for future research. One purpose of her article was to "try to avert a long period of stalemate while an over-used theory slides into decline" (1994: 17). Solomon concludes that too much has been claimed by constructivism, and too much expected of it.

Mature constructivism tends to abrogate all avenues of research to itself. Even its opponents accept this [and argue] for example ... that constructivism is flawed because it fails to come to grips with issues such as culture and power in the classroom. But no single perspective is ever likely to provide a final description of science education. To equate the absence of such total coverage with theoretical error illustrates once again the overblown expectations that have accrued to constructivism. (Solomon, 1994: 17).

This situation described by Solomon, and the debates in New Zealand sparked off by Michael Matthews' (1993) criticisms of constructivism, provide the setting for this article. It is important to recognise that constructivism's own theoretical difficulties probably account for only a part of its vulnerability to critique. Just as important is the fact that the political climate is no longer in sympathy with the idea of knowledge as a human construction - especially not at the level of the school where students are expected to proceed in an orderly and efficient way with the acquisition of knowledge and skills, as exemplified in the areas and levels of *The New Zealand Curriculum Framework* (Ministry of Education, 1993), and the *National Qualifications Framework* (New Zealand Qualifications Authority, 1993).

I share Solomon's concern that constructivism attempts, or is expected to attempt, to cover too many of the aspects and issues of science education, and that this may lead to a stalemate. It would be a loss if as a consequence the useful work accomplished so far were demolished along with what is seen as no longer appropriate.

I cannot comfortably suppose that if constructivism is replaced this will be because something better and more complete has been developed, which deserves to replace the flawed approach of

constructivism. Unfortunately, the history of science education does not present a picture of an evolutionary improvement (De Boer, 1991). Rather it appears as if the weaknesses of one approach, or a shift in focus in society - such as the present focus on orderly acquisition of pre-set standards and qualifications - simply leads to a switch from one approach to another, with regular reappearances of old, previously rejected approaches. If a radical change is made, we are just as likely to end with something that was found wanting in the nineteenth century, as with anything that represents an improvement on constructivist ideas.

Gender issues and constructivism

Constructivism has contributed a great deal to our understanding of science learning. It has more to offer because it gives a central place to the recognition of science as constructed knowledge. This is in accord with the various feminist critiques of science, and provides a starting point for dealing with issues of gender and race. However, researchers in the constructivist tradition need to meet a double challenge of overcoming a now hostile political climate, and readjusting their perspective to deal with the internal problems their approach faces.

The five areas that I discuss in this paper as problematic for constructivism are the ones which lie - often unacknowledged - at the heart of any educational theory or practice. The five areas are inter-related in a network of knowledge production and transmission which is linked profoundly with masculinity (Gilbert, 1994). None of these five areas can be changed in any fundamental way if corresponding changes in the others are not made.

Early constructivist research (Osborne and Freyberg, 1985) clearly showed major problems with science learning at that time. Constructivist research and practice now has as its project fundamental changes in the way students learn and teachers teach. This potentially radical change is incompatible with the network of ideas about the nature of the individual, the nature of science, and the nature and purposes of education which govern the educational environment in which constructivist changes are proposed.

An important contribution of constructivist researchers has been to issues of girls and science. Bell's (1988) work in particular, has recognised that girls do not have a sense of belonging to science and this is necessary for full participation in science. Various means have been explored of "using the experiences, interests, and concerns of girls, Maori and Polynesian students in the classroom as well as those of boys" (Bell, 1991 b: 45). Building on these explorations, the statement in *Science in the New Zealand Curriculum* (Ministry of Education, 1993:11) says

... the curriculum in science should recognise, respect, and respond to the educational needs, experiences, achievements, and perspectives of all students: both female and male; of all races and ethnic groups; and of differing abilities and disabilities. An inclusive curriculum that recognises the perspectives of a particular group of students can enrich education in science for all students.

There already exists a significant body of literature which advances a feminist critique of the networks of knowledge production and their link with masculinity. For example, Harding (1986), Haraway (1991), and Keller (1992) write about the value-laden nature of scientific knowledge and how it excludes women and the feminine. Martin (1994) writes about how education itself, its philosophy, its purposes, and all its curricula, exclude women and the feminine, and indeed exclude anything to do with continuation and reproduction of human life and human society. Walkerdine's (1984, 1989a, b) work has dealt with the gendered nature of the individual in relation to education.

These works make it clear that science education, and the individuals who learn, are part of one extended dream about masculinity. There is no room for the feminine in girls or boys, nor for any change towards non-gendered or gender-neutral science education.

For this reason, in order to write about gender issues in constructivism, I had to move away from the classroom and its immediate concerns. I had to move into an examination of the

overarching models of reality which shape educational practices, and which circumscribe the limits of educational possibilities.

Constructivist researchers have, until now, focused their significant contributions on the classroom activities of learners and teachers. With this base firmly established, they might choose to look more widely now, and examine the way in which their classroom concerns are intimately linked with, if not determined by, the knowledge base of science, notions of the individual, and of education itself. In order to develop a fuller theory and practice for classroom learning, including that of girls, these wider networks should be a central part of future research. In the comments I make below, I hope to encourage constructivist researchers and practitioners to widen their area of enquiry to examine the extent to which, as things stand, their young learners engaged in personal and social cognitive change can only be little masculine, European, Cartesian knowers; and their classrooms and teachers can only be what is already envisaged by the wider networks in which they operate.

In a sense what goes on now in science and science education is implicitly about a certain world - ours - in which all positive values are linked with the masculine. In the same sense, my comments and suggestions in each section that follows, while not always explicitly mentioning gender or girls, are implicitly about a possible world in which the entire enterprise of science and education is not founded on a series of oppositions, all linked with an opposition between feminine and masculine as one of primary givens of our existence.

Issues for future constructivist research

The nature of science

Does science deal with universal facts or culturally relative truths?

Traditional approaches to science teaching suggest the former, and have pedagogies to match which stress the orderly acquisition of a body of internationally accepted knowledge. The students' role in constructivist pedagogy suggests the latter, since they work on constructing their own conceptions where their own beliefs, experiences and values play an important part. The teacher's role implies guiding the student towards the universally accepted scientific ideas. As Solomon (1994:14) has recently written "Constructivism ... has always skirted round the actual learning of an established body of knowledge".

Science education is likely to incline in practice towards the conception of scientific knowledge as basically real, true and factual. However, it is important for both students and teachers to work regularly with material that brings into focus the ways in which scientific knowledge *is* culturally shaped.

Keller (1992: 91), writing about the tension between science as fact and science as culture, and also about how students might respond to it, concludes:

Out of their [scientists'] interactions with each other, with the public at large, with their own heritage, and with a judiciously culled set of facets of the inanimate world, they have succeeded in producing tools that appear to dissolve nature's resistance to our own needs.

But in marveling over their extraordinary success, we need also to consider the almost equally remarkable particularity (perhaps even singularity) of our needs, of the facets of the natural world we designate for experimental and theoretical enquiry (that is, what it is we seek to know about), and of the social arrangements that facilitate the convergence of these needs and facets.

A formulation like this could form the basis for future constructivist thinking about the nature of science in science education. What Keller does is to give an important place to the natural world and to the success of the tools produced through science which relate to this natural world, while at the same time expressing how much of what we see is determined by human social organisation.

Constructivist ideas of science (Bell, 1991 a) have had to counteract the notion of science as *facts* about the *real*/world, however they have perhaps erred a little too far in emphasising the role of observation and personal construction of theories. The precise balance between the natural world and social interactions and forces which lead to particular facts and theories is not easy to achieve, and difficult to express simply. It seems very important that this is done well since charges of relativism, which seem convincing and alarming, are easily made (Matthews, 1993: 14) if there seems to be too little emphasis on the reality of the physical world. The time may now be ripe to allow a more complexly nuanced view of science to develop in harmony with constructivist theories of learning.

How can critiques of science (Maori, feminist etc) be productively worked on within science education?

Feminist critiques and those which critique science as an expression of Western European culture, have made it clear that science cannot be viewed as the discovered truth about the *real*/world. Keller's ideas quoted above provide one way of seeing how science can be right, and the critique she expresses so well in her second paragraph can be right at the same time. However, Keller is a scientist and a theorist, and science students are not in the same position of being able to operate at the forefront of meta-theoretical thinking. As Solomon (1994: 16) has observed, "Changes to theory do occur, but they are certainly not brought about by school pupils who have difficulty in comprehending science textbooks".

The problem for science education seems to be how the critiques can be built into the *real*/work of learning science in advance of these critiques having achieved any widespread success in bringing changes into science itself (Gilbert, 1994).

What kind of truth can students arrive at by using their own senses and studying everyday objects?

Constructivist theories of learning expect that students will engage their senses with objects from the external world and as a result (re)discover or understand scientific facts for themselves. The key postulates of the generative learning model certainly suggests this (Osborne and Wittrock, 1985: 64-66), and this model is central to the constructivist view of learning in science (Bell, 1993a: 23).

There are long-standing philosophical arguments against any simple version of this idea. Recently Suchting (1992) has critiqued Glasersfeld's constructivist theory at length, and Matthews (1993) and Osborne (1993) have argued that using this kind of empiricist methodology in science education, based initially on a realist view of the world, immediately leads to a relativist ontology.

There is a strong tradition in educational thought which demands the engagement of childrens' bodies and senses with the objects in the physical world, and not just with language about that physical world. This educational approach is strongly supported in New Zealand by a general cultural preference for each individual to have hands-on, commonsense skills in all aspects of life.

It would be helpful if future constructivist theoretical work were to elaborate a detailed account of how constructivist ideas about meaning, communication and scientific understanding relate to sense data, to macroscopic objects, to theoretical constructs, and to all "the facets of the natural world" (Keller, 1992) with which science chooses to deal.

This is a difficult problem since the classroom methodology and the ontology behind it must make sense together. They must both be appropriate for young 5 year old children as well as 18 year old and adult students studying secondary science. Almost certainly some differentiation will be required in the conceptions of the physical world and science students' relation to it, at different ages, and different stages of science study.

The problem here is that this issue has an ancient and complex lineage in Western philosophy that is intimately linked with the development of modern science. Although limited and pragmatic notions may be used at times about how all or various students learn in classrooms, constructivist thinkers must have available an account of students, sense data, visible objects and *truth*, which has an adequate compatibility with philosophers' treatments of the problem.

Can the goal of increasing scientific knowledge be disassociated from a belief in economic and technological progress and be subjected to ethical judgements?

Science is strongly linked with the current government goals for New Zealand. As a result of the United States' declining position in world trade, President Bush initiated a policy, which President Clinton has followed through, to make U.S. students first in the world in science and mathematics by the year 2000 (NAEP, 1993: xvii). The current political philosophy of both National and Labour Parties in New Zealand links science and economics in a mutually interdependent force which is represented as having the status of a natural law. Progress towards greater wealth is taken as progress towards a better life for New Zealanders. This progress is impossible without forward movement on the economic-scientific front. Even maintaining the existing quality of life is said to be dependent on the same forward trajectory.

We live in a world that is increasingly influenced by advancements in science and technology. To lead the rest of the world, or even to keep up with the rest of the world, it is vital that all students develop a sound appreciation and understanding of science at each level of the school system. (Smith 1992: 5)

It is a discourse which links science with economics in an inevitable fact-driven trajectory towards human *progress*. This discourse is often used to override individual, local, emotional, aesthetic and moral needs. Issues are dichotomised - with science, reason, progress, prosperity and improvement on the one hand; and emotion, nonsense, conservatism, poverty, and economic and social stagnation on the other.

It is difficult to forward any other view-point since science is the truth-test of every statement or opinion. If a claim is made about any aspect of the world susceptible to formulation in any branch of science, then it must be subjected to a scientific test of truth. If claims are made about areas relating entirely to human behaviour then they must pass a test of truth formulated along the same lines as a scientific experiment, since only that counts as proof. If no other form of proof is available the claim may be validated by profitability in the free market, since the free market supposedly depends on the operation of a *natural law*.

This is no accidental alliance. The roots of modern science are closely linked with the rise of the capitalist economies (Foucault, 1981). Research money is used to continually enforce and reinforce this linkage.

Science students should not feel obliged to buy into the science-economics identity in order to study science. Girls seem particularly sensitive to this conflict (Gilbert, 1990). They should not face an apparent choice of either accepting a particular political-economic world, and the science that goes with it; or rejecting science, in order to reject aspects of a political-economic system. A similar observation has been made by Keitel (1995) about Mathematics education, where students are faced with the choice of either blind acceptance of mathematics as pure, universal, and detached from the political world; or, if these characteristics are seen as personally unacceptable, but essential to the discipline and unchallengeable, then a rejection of mathematics.

If no particular message comes through in science education, the messages from students' life outside the classroom will seem to many secondary school students to offer only two possibilities - a choice between ultimately amoral scientists, and moral non-scientists. To some extent, constructivist research has tried to confront this issue by including social issues and debates in science curricula. More is needed and constructivist science educators face the challenging task of

getting this issue raised and at least partially resolved at the highest level - universities and polytechnics, practising scientists, politicians interested in science, in education, and in economic development, and agencies which fund scientific research and development.

What is the relationship between students' understandings and those of scientists?

Much of the constructivist research in the *Learning in Science Project* (Osborne and Freyberg, 1985) began from the view that students had misconceptions about science ie. they did not correctly understand what actually took place in various scientific phenomena. The goal was to enable children to overcome these misconceptions and understand the correct, scientists' view.

On the face of it, Matthews' (1993: 13) response to this idea is not an unreasonable one: "One would think that if they *have to* construct the ideas of scientists, they could more easily be told them". The LISP researchers had already been there, because they had discovered that no amount of *telling* was able to change some students' ideas (Osborne and Freyberg, 1985). Their efforts to find a way to help students move past those *erroneous* ideas that telling could not shift was the motivation for adopting and developing the Generative Learning Model.

Are students expected to have the scientists' views of scientific phenomena? At least in one sense students' ideas must be different from scientists'. Even when they are *correct*, students' views are inevitably much less elaborated than the scientists' views. They are also different in that each concept forms a much larger part of the much smaller totality of a student's scientific understanding.

Constructivist writing has certainly drawn attention to the differences between students' science and scientists' science, and some of the issues this raises, such as how and when a student's science is judged to be close enough to a scientists' view. So far, constructivist writers have not focussed on these issues (Osborne and Freyberg, 1985: 62; Osborne and Wittrock, 1985: 69, 78-79; Bell, 1993a: 28, 34-5.)

It is probably necessary now for this to receive considerable attention from constructivist writers. The climate of educational politics with its focus on credentialling, and demonstrated stepwise progress towards set objectives throws into sharp relief issues of what is required, and what is correct, at a given stage. It must always be a central issue in school science to deal convincingly with the relationship between scientists' views, learners' views and the nature of the learners' progress, and such issues are particularly under the spotlight at present.

The purposes of education

How do you reconcile the competing claims that education is for the individual, for society, for the economy etc?

The statement of the General Aims of Science Education in *Science in the New Zealand Curriculum* (Ministry of Education 1993: 9) expresses this issue - as if there were no problem.

Science education contributes to the growth and development of all students, as individuals, as responsible and informed members of society, and as productive contributors to New Zealand's economy and future.

These words express a cosy unity of purpose among students as individual human beings on the one hand; and on the other, students as *informed* members of society, as *responsible* members of society, as productive contributors to the economy and to the nation's future. That these are in a happy, co-operative, positively beneficial union is one of the myths on which the education system is based.

Constructivism has thrown the spotlight on one side of this conflict - apparent learning without real understanding by the learner is worthless. As students progress to secondary education and

through it, the other side is increasingly in focus - what use is individual understanding if it is different from the learning that is valued and rewarded in examinations, and in the world of work?

Beeby (1992: 288) suggests that this is Kant's philosophical problem of the tension between necessity and the freedom of the will; and between duty and happiness; and that it is always with us. There seems at the present time to be a particular stress in the community on the necessity and duty side of the tension. While constructivism has generated insights and strategies on the individual side, which relate to the freedom of the will to follow its own interests, it may be time now for constructivist thinkers to direct attention to the other side - to issues of necessity and duty, of science education not *for* the individual, but *for* the society, and *for* the economy. If further thinking on this side of the issue is not developed in harmony with constructivist insights about the individual, the conflict between individual and social purposes of education may well be the issue which leads to constructivist approaches, with their emphasis on the individual, being excluded - from official recognition in science education.

This tension between necessity and freedom of the will is particularly strong in science education because of the critical importance science is considered to have for society, and the consequent demands placed on its utility. The fact that science is so important gives science educators a lot of power - what they say and do *matters* crucially to the nation. For this reason, it seems that science education is the most likely area in which progress could be made past excessive dichotomising of this tension, and towards a more fruitful conception of the balance between individual learning, and social and national needs.

What is perhaps another form of the same dichotomy appears in the contradictory demands of employers for the education system to produce compliant workers with pre-determined skills and knowledge, who are nevertheless creative and dynamic. This is generally seen as an opposition throughout education, in the sense that they are thought of as attributes of different individuals rather than as aspects of the same individual, and this differentiation is linked with sex and gender dichotomies (Walkerdine, 1989a). Diligent, careful and skilful mastery of pre-set knowledge and routines is seen as a feminine attribute, while dynamism and creativity as masculine. One might argue that science requires individuals in which the two aspects are integrated. If science educators were able to lead the way in integrating these two aspects, and in disassociating them from gender, they would be making an innovation of enormously productive and liberating potential.

The nature of individuals

The rational or the social individual?

Science educators have to work with the two disciplines of science and of education. When they think about the individual learner, is their *individual* the complex, diffuse, sensitive and contradictory individual of the social sciences, education and psychology, or is it the unified, rational individual as conceptualised by the scientific-economic view? Whether constructivism takes a personal or a social view of the construction of knowledge, the same problem remains that the scientific-economic rational individual is at the heart of the world of science. This involves being a particular individual ie. white, male etc (Walkerdine, 1989b), and never giving priority to ways of looking at the world which are not among the "judiciously culled set of facets" (Keller, 1992) which science chooses to explore.

Constructivist thinking on learning tries to give a place to the personal, the individual, the social, but this is inevitably at odds with the world of science. Which of the two individuals will win out in science education at the level of national policy? It seems inevitable that it will be the unified, rational, scientific-economic individual who is in harmony with the perceived needs of the economy. This dichotomy of the individual, like that of the individual versus the national economy, is harmful both to the individual and the nation. If constructivist science educators could contribute in future

research to dissolving both these dichotomies, many limitations on the scope of science, and on the breadth of participation in science would be removed.

The individual or the group?

If constructivist research moves on to focus more on the social (rather than personal, individual) construction of knowledge (Bell, 1993a: 28), this would add a rich and important dimension to the thinking. It will also mean some very important work of conceptualising how the personal and social aspects of individuals can work together in science education. The issues about science's conception of the individual outlined above are complex in themselves. It will be a very challenging task to produce a reworked version of that conception. It will be even more demanding to reconcile that with an integrated conception of all the young and older students in science education as actors in their own individual and social lives. Even on the narrowest conception of the social, at the level perhaps of the family, the individual and the social may well be in conflict in relation to all learning - and perhaps particularly in relation to science learning.

Individuals or method?

A simpler problem is one that Osborne (1993) deals with at some length, citing a considerable body of research on individual learning preferences and differences. Constructivism focuses on the individual learner, but strangely suggests that all individuals will be suited by constructivist methods, with their emphasis on questioning and exploring, rather than telling. Research on individual learning, however, generally shows numerous individual differences in preferences and strategies. Some students prefer to master a considerable body of knowledge and delay personal construction of meaning until they feel they can confidently manipulate externally given meanings. This is contrary in spirit to the Generative Learning Model, and more in keeping with a behaviourist approach to instruction.

How students learn

Constructivism as a psychological and a pedagogical process

In education there is always some tension between coming to understand in a personal, psychological way, and coming to understand in relation to the curriculum, and the demands of the system for evidence in the form of assessment. Constructivist work has focused well on the former, but has paid much less attention to the latter. The Generative Learning Model is most readily interpreted in the light of individual learning experiences at the level of the lesson (Bell, 1993a:66-67). Wider interpretations of construction of meaning which could operate over the span of a year, or more, of instruction, are obviously not included.

In fact, most constructivist work has had a relatively narrow focus on the individual student's thinking within a single lesson, or sometimes a unit of work. In order to contribute to a comprehensive approach to science *education* (not just the science lesson), a broader constructivist view is needed which pays attention to students' strategies for managing the demands for new thinking in several school subjects, plus their workload of assignments and lesson preparation, as well as other aspects of school life. Some of these considerations could account for why some students may prefer a highly structured, didactic programme and method, in which some of the demands on them are limited and simplified.

How far can we go with conceptual change?

The notion of conceptual change has been very productive in constructivist research, but to give a fuller picture of student learning it needs to be complemented by other ways of thinking about how students learn. Ideas of conceptual change tend to focus on the "resolution of a major conflict, for example, by the replacement of the student's conception with the science ones" (Bell, 1993a: 25). This is probably a relatively unusual experience in learning, and constructivist researchers point out the resistance of student ideas to this kind of change (Gunstone, 1991: 26). Both he and Bell mention other kinds of learning - conceptual development and conceptual resolution - which are more gradual and less dramatic, but these are not developed as a major focus of constructivist learning theory.

There are aspects of learning which are better captured by metaphors of growth, elaboration, gradual synthesis and gradual transformation with no sense of juncture. These ways of thinking about learning are not antithetical to a view of learning as personal construction, but they work in a longer time frame and focus on how the mind and body can sometimes do its own work in integrating learning, without always being subject to the conscious procedures of the Cartesian thinking subject. It would be very exciting to see future constructivist work on these ways of learning, which lead into somewhat different areas from the previous constructivist focus on student misconceptions and conceptual change.

In what ways is science education like science?

Solomon (1994: 16) suggests that at the heart of constructivism is "the notion of the pupil as already the scientist". Logically, there is no reason to think that this kind of realism, or face validity, has any advantage in learning; rather, it has disadvantages in that it suggests students and teachers should aspire to many inappropriate and impossible types of behaviour, while avoiding other useful strategies because scientists do not practise them.

Science students are not scientists, except very occasionally when they engage in genuine research projects. The rest of the time they are young school students learning science. There is no reason to assume that the best way to learn the discipline is to copy the behaviour of qualified practitioners. In learning a discipline it is intended that the student will learn much faster than the rate at which the knowledge was developed. Otherwise, one would always have to go through years or centuries of painstaking research to recapitulate the whole process.

Learning a discipline involves quite different processes. Some part of it may involve simulating the work of the practitioner to learn their specific work skills. Most of it involves covering a body of knowledge and procedures in whatever way is efficacious. If the notion of the student as already a scientist is really at the heart of constructivism, it would be helpful to elaborate more fully exactly how widely and deeply this metaphor can be usefully applied in science education. Misunderstanding about how far the metaphor is to be pushed possibly underlies criticism such as "New Zealand children do not need to reinvent the scientific wheel". (Matthews 1993:13).

The role of teachers*Conflict between content and method*

Science teachers are the representatives of the *hard* science versus most of the other disciplines in the school which are *soft*. Science teachers are not really *hard* themselves for two reasons. First, they are not exactly scientists themselves (usually), but only relatively advanced students, who must appeal to the real experts outside. Secondly, they are school teachers and education is *soft* not *hard*. Therefore both they and their students are in an ambiguous position in that most of what they do does not exactly count as *hard* science.

The content they are to teach is hard, defined, important, male, factual, belonging to the outside, public world, and quantified. The method they use to teach, their pedagogy, is considered by contrast to be soft, fuzzy, peripheral and optional, female, psychological, belonging to the domestic world of school and children, and qualitative (Walkerdine, 1984). To a very large extent the content is given. The teachers' methods are their only area of true expertise. This places both them and their students in a subjected position from which it is difficult to claim a sense of real participation. Is it possible for teachers, and students, to have a relationship of ownership with science? This question has yet to be explored by constructivists.

Conclusion

Working through all these dilemmas will inevitably mean some changes to the ideas of constructivism. People who have researched or taught using a constructivist approach have contributed an enormous amount to the understanding of how children learn science, and there is more to be learned. It is certainly important to figure how we construct personal understandings, how these relate to the common every-day understandings of our society, and to the specialised understandings of particular knowledge systems like science.

Constructivist thinking still has a lot to offer in this area -particularly if it can be well integrated with compatible theories of science, curriculum, learning, and teaching. Dealing with these areas will require reaching out quite widely to traditions in political thought, philosophy, sociology, feminism, as well as science and education. Then there is the difficult work of integrating disparate ideas into a view of science education which has the constructed nature of science and learning as a central idea. Given that they would be dealing with the very foundations of our world, nobody could expect constructivist researchers in science education to come up with *the answers*, but it is hoped that they will formulate and explore questions to open science more to girls, along with other excluded groups.

If their research agenda for the future does not deal with at least the dilemmas and contradictions discussed above, they will lose their position of influence in science education to groups who are able to demonstrate some weakness in the constructivist position. In spite of the criticisms that can be, and have been, levelled at constructivist approaches, at present no other approach offers more, or even as much.

The challenge for constructivism, as I see it, is to offer real advantages to *all* science students - girls and boys, of all communities and ethnic backgrounds - by continuing to make progress on the difficult issues in science education.

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