Constructivism: an overview and some implications

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Introduction

Constructivist theories are about knowledge and how we 'come to know'. They are accepted by many educators, particularly in mathematics and science education, and represent a major challenge to behaviourist traditions. In this seminar I intend to give an overview of constructivism, some implications from it, and some criticisms of the theories.

Constructivism needs to be seen amidst the other theories and influences on teaching and learning and as part of the development of education from its roots in psychology and prior to that in philosophy.

Since the 1950s, in New Zealand and other Anglo-American countries, the dominant theories in education have been behaviourist. These theories break knowledge into specific objectives, and are more concerned about measurable behaviours than about what the learner is thinking. Other theories such as Dewey's (1902) progressive education have had some influence on education in New Zealand and the 'playway' notions that Beeby introduced into New Zealand in the forties were evidence of this. We have paid little note to Gestalt ideas from Europe that suggest that subjects should be looked at more holistically, while in my own field, mathematics education, we have only recently considered the implications of ethnomathematics that suggests that mathematics, like other subjects is culturally dependent.

Constructivist theories have challenged the dominant ideas of behaviourism. They start from non-positivist perspectives on knowledge and understanding, they are theories about 'how we come to know' about learning. From this beginning people have taken the ideas and teased out some implications for teaching, assessment and curriculum.

Positivism and Constructivism

Positivists have the notion that there is an external world independent of the observer and that the observer is able to make sense of this world and understand it. Such an accurate understanding of the world implies that a shared understanding is possible, and education should therefore be concerned with ensuring that students come to share this understanding.

In contrast, constructivist do not deny the existence of an external world that is independent of the observer, but they claim that the observer cannot know this world. The observer makes meaning of this world by constructing a representation that depends not only on their sensory input, but also upon all their prior learning and experiences. As each person has unique experiences, each person's construct will differ. In as much as people have similar backgrounds and similar views, the possibility for a significant amount of shared construction exists.

Some Historical Notes

Constructivist ideas have a long history in philosophy with some aspects dating from Xenophanes, a 6th century B.C. sceptic, who said that if someone described exactly how the world really was, they would have no way of knowing that it was a true description (von Glasersfeld, 1990). This major argument of the sceptics for the last 2500 years assumes that all ideas and knowledge gained is derived from our experiences - our senses, our acting and our thinking. Such ideas continued to emerge in debates between objectivists who believe that things can only be known objectively and that knowledge is outside the mind, and the relativists who believe that all knowledge is subjective. These ideas were made explicit by Vico who lived from 1688 to 1744 and wrote a treatise (Vico, 1710) on the construction of knowledge (von Glasersfeld, 1990), he said “the human mind can only know what the human mind has made”. This statement differentiates between knowledge of the real world and knowledge of the world as a mental image that we create from our experiences.

Constructivism

While the sceptics, Vico, and also Locke and other thinkers are sources of constructivism, Piaget is “the great pioneer” (von Glasersfeld, 1990). In summarising Piaget's contributions von Glasersfeld argues for two principles:

1 Knowledge is not passively received either through the senses or by way of communication. Knowledge is actively built up by the cognizing subject.

2a The function of cognition is adaptive, in the biological sense of the term,

tending toward fit or viability.

2b Cognition serves the subject's organisation of the experiential world, not the discovery of an objective reality.

In von Glasersfeld's terms, people who subscribe to the first of these principles are called 'trivial constructivists' while those that subscribe to both are 'radical constructivists'. Von Glasersfeld has argued these principles as a philosopher rather than as an educator. His influence has been significant in mathematics education and it was in this area that I came to know his work. I would see myself as a radical constructivist (although with some misgivings), and this may help to explain some of the bias I show here.

Apart from Piaget (1937), the other pioneer of constructivism is Vygotsky (1962). His ideas are generally called constructionism, or social or socio-cultural constructivism. Vygotsky believed in the primacy of culture in shaping development. His view of instruction was that interaction with adults or more advanced peers was necessary for development and that this required the active involvement of all participants. He assumed that instruction influenced development, that the teacher can intentionally nurture and teach children only in collaboration with them, and that this process requires the teacher to move ahead of development into what he called a “zone of proximal development” (Howe, 1996). Gergen (1985) has said that a social constructionist, as compared with a behaviourist, would: take a critical stance towards taken-for-granted knowledge; make sense of the world in ways that are always historically and culturally specific; accept that knowledge is not derived from the nature of the world as it really is but is sustained by social processes (especially language interactions); assume that negotiated understandings that we call social constructions sustain some social actions and exclude others.

I do not believe that social and radical constructivism are incompatible positions. The radical constructivists do not deny the importance of social interactions nor that experiential worlds are historically and culturally specific. Social constructivists accept that negotiated understandings do not exclude the notion that different individuals may have different constructions. I see these two perspectives as two ways of looking at knowledge construction, one reflecting Piaget's background as a biologist and emphasising the organising individual, the other reflecting Vygotsky's background in a communist state where collective phenomena were emphasised. However, the two ways employ different dominant metaphors for the mind and for models of the world.

From a radical viewpoint I assume that there are at least as many varieties of constructivism as there are people claiming to know what constructivism is about. So far we have touched on three of these, trivial, radical, and social constructivism. Ernest (1994) considers four varieties and their differences are summarized in table 1 below.

Table 1: A constructivist classification (derived from Ernest, 1994)

Type of constructivism	**Metaphor for the mind**	**Model of the world**	**Epistemology**
Information-processing	Computer, unfeeling thinking machine (Scientific Realism)	Absolute space, with physical objects	Objectivist or absolutist
Trivial	'Soft' computer (brain as machine) (Scientific Realism)	Absolute space, with physical objects	Objectivist or absolutist
Radical	Evolving, adapting. Isolated biological organism	Subject's private domain of experience	Subjectivist, relativist, or fallibist
Social	Persons in conversation	Socially constructed shared world	Subjectivist, relativist, or fallibist

In education constructivism is sometimes thought to be limited to mathematics and science but this is only because of the emphasis that these educational groups have put upon it. The books of Littledyke and Huxford (1998), Geering (1994), and Sacks (1989) show constructivism across the primary curriculum, in religion, and in the education of deaf people and the use of 'sign'.

Other variations of constructivism exist. Critical constructivism will be mentioned later as a response to some of the criticisms of constructivism. “Situated cognition” is another variation - perhaps the most well known form of this relates to “communities of practice and legitimate peripheral participation” (Lave and Wenger, 1991) although this seems more concerned with adult learning rather than young children in schools.

An Example of Knowledge Construction

I would like you all to participate in a 'thought experiment' (Jaworski, 1994). Imagine that you have arrived at an unfamiliar city or at a conference in an unfamiliar university or conference centre. Now think about how you develop your 'mental-map' of the city, university, or conference centre from when you first arrive. Your 'map-making' may be aided by a paper plan of the place, or by verbal instructions given to help people get from one place to another. Our knowledge is built up over time as a

result of our experiences until we have a model of the area that is at least adequate for our purposes even though it does not involve all the actual details.

From this example and from the above principles we see the emphasis on experience - on the one hand the active experience during learning (what did you find at the new city or at the conference venue), and on the other, the prior experiences which are being reconsidered and adapted as the new experiences are assimilated (what do you expect in virtually all cities and what had you assumed from earlier conference participation).

These experiences related to present and past learning, they included experiences associated with language such as listening and discussing, which occur in formal learning situations (the classroom) and in the general experiences of everyday life. Learning is the organisation of these experiences to make a coherent and viable picture of one's world.

From a radical perspective 'meaning-making' is seen as individualistic. It is assumed that each learner reconstructs their existing understandings to take on new ideas. It certainly is true that in our thought experiment and from our experiences in a city or at a conference, we do have different mental maps. From a Vygotskian approach the learning environment is seen as the social milieu that affects the actions taken by learners, and knowledge is socially constructed through the use of language (signs and symbols) in a social context. Through these social interactions cultural meanings are shared and the individual is enculturated. Again, in our thought experiment we see evidence of this and the commonalities of our mental maps mean that we can communicate socially about the city or the conference venue and through these communicative interactions our maps are further developed.

Constructivism in Education

Constructivism then, is about how we 'come to know', but as teachers when we consider theories about learning we also want to know much more. We do want to know how students learn, but also how this might affect how we teach and how we assess, and how might the curriculum is influenced. While these four aspects are obviously interrelated I will discuss them separately.

Implications for Learning

Seven implications of constructivism for learning drawn from educators (Becker and Varelas, 1995; Boulter and Gilbert, 1995; Confrey 1994; Salomon and Perkins, 1998; and von Glasersfeld 1989, 1995) are expanded below:

- knowledge is personally constructed from new experiences *(personal construction),*
- every learner has ideas prior to learning and these affect the way that they make sense of what they are being taught *(prior learning),*

- learning is not transmitted by linguistic communication but language is a tool to help students construct knowledge *(role of language),*
- individual constructions should fit with the accepted views of communities of practice *(accepted views),*
- theories about the world are provisional *(theories are provisional),*
- contexts are important in learning *(context),* and
- learning is a participatory process *(participation).*

Personal construction

Personal construction means that individuals make unique sense of their own experiences. Some experiences, especially ones that occur in schools, are similar for individuals, but others are different, and even similar experiences can be interpreted in different ways. Some of the different ideas that learners construct will be acceptable while others will be seen as alternative- or mis-conceptions. This might suggest that learning is a private matter but learning is an active process and social interaction is one activity that helps people learn. This is evident from the way that people develop their ideas when they are explaining or discussing them and collaborative learning that provides opportunities for social interaction is seen as advantageous for learning.

Cognition being adaptive (Principle 2b) has been interpreted by some as meaning that no absolute reality exists. This is not what is intended - saying that knowledge is relative and that we are not able to know an absolute reality is not to deny its existence. Constructivism implies that each of us personally constructs (Piaget suggests by accommodation or assimilation) what constitutes a viable fit with our experiences and our best interpretation of what we have learnt from others, and this knowledge is unique to each of us. This 'best fit' is usually an adaptation of prior learning that links new experiences in a way that minimises cognitive conflict.

Prior learning

If thinking (cognition) is adaptive then making sense of experience depends on what was previously known. This suggests that to facilitate learning teachers need to become aware of what learners already know. This awareness can be increased through informal interaction during teaching (informal formative assessment), through experience, and through sharing sessions with colleagues. While prior learning differs between individuals, many will exhibit similarities in their prior ideas and their

alternative conceptions about topics. Of course finding out what students already know is not restricted to the constructivist paradigm.

A useful metaphor to help understand the constructivist learning process is to consider a 'knowledge schema' (or a concept map, a web or a 'graph') in the mind of each learner. Before a learning activity the student has a schema which involves pre-school prior experiences, in-school experiences, and out-of-school experiences from everyday life. Learning can be imagined as a process whereby new ideas are constructed and added to existing ideas on the schema and as making connections between ideas on the schema.

For school learning to be meaningful it is desirous that one schema exists for a particular topic - not one for real life and a separate one for school knowledge, and that things learnt in school are connected to things learnt in other situations. Unfortunately learners often seem to have two or more schema, or one with disconnected parts. One sees evidence of this lack of connection when a learner has grasped a topic (such as graphs in mathematics) but is unable to use it in a different context (say science). To help students make all these connections teachers need to have both a good knowledge of the subject and of the other experiences (school, cultural, and everyday) of the learners.

Role of language

While knowledge is not passively received through communication, this does not alter the fact that language (including symbols, signs and gestures) has an important role. Knowledge is actively built up and all experiences including language experiences and social interactions are part of the experiences that contribute to knowledge. The prior ideas that contribute are shaped by language which is an integral part of culture and this provides the context in which experiences occur. One implication of this is to move subjects such as science and mathematics from being viewed as language and/or culture free or as part of an objective reality; to something that is unique to each learner, and that reflects their language abilities which in turn influences how they organise and make sense of their experiences and how they are able to communicate with others.

Accepted views

While meaning is constructed individually, there are some negotiated understandings (truths) that can be regarded as socially agreed upon by a community of practice when defining their subject. Indeed Geering (1994) talks of the role of story telling and myth creation as we build understandings about religion, and Bell and Gilbert (1996)

emphasise anecdoting as a process by which teachers come to understand each other's practice.

It is useful to think of the different domains in which meaning is constructed, these are the individual, the common, and the official public domains (Boulter and Gilbert, 1995). They correspond to levels of understanding, the first being the individual's private understanding or what might be thought of as their mental model. In the second there is the common socially negotiated understandings that are built up as a result of social interactions. The third represents the views of 'experts' and might be thought of as accepted 'correct' knowledge or the best explanation that at exists. While a teacher would like to know what a student's ideas are, they can only get to the expressed model which might be regarded as somewhere between the individual and the common domains.

From this view of learning one sees education as helping shift the thinking of learners so that their individual models are as close as possible to those of the experts. In accepting the need to negotiate understandings within communities one assumes that teachers have an adequate background in their subjects so that they will know which ideas are acceptable within the relevant communities of practice.

This negotiation of meaning towards the accepted views can occur at the personal level through reflection and discussion. It can also be facilitated by teachers who provide well structured (and often directive) learning activities - this is sometimes not thought of by teachers as constructivism as they have mistakenly assumed that learning must be through discovery within an 'anything goes' environment. An example of a directed activity might be this lecture - I assume that my role is to provide ideas and that your knowledge is being constructed as you accept (accommodate or assimilate) or reject these ideas through an active thinking process.

Theories are provisional

The idea that any theory, schema or model that one constructs about any topic is provisional follows from the idea that learning is personally constructed and that cognition (coming to know) is an adaptive process. Thus, if one constructs an idea to make sense of one's world, then a new experiences may result in a need to change one's theory. One sees this in mathematics when we talk of square roots, firstly $\sqrt{4}$ (=2) is accepted and not $\sqrt{3}$, then $\sqrt{3}$ is accepted and most students assume that $\sqrt{-4}$ is not possible, but later they meet imaginary and complex numbers. Similarly in science students might think of an animal as something like a cat or a dog or a farm animal, their idea may include wild animals, but usually it takes time before their ideas move so that birds, fish, insects and humans are all seen as animals.

In science education there has been much discussion about conceptions and misconceptions, and the term alternative conceptions has been used to ensure that the learners' ideas are valued for what they are. A conception might be viewed as acceptable to a community of practice, a misconception as unacceptable, and an alternative conception as something that fits most of the facts and seems viable within the learner's experience. These alternative ideas often emerge as an early attempt by the learner to understand an idea. Finding out what these ideas are is one way for the teacher to develop an understanding of what is going on in the student's head. This then provides a starting point for teachers to challenge the understandings and to help the learner reconcile contradictory ideas that they may be holding at the same time. For example when we see 5/10 + 7/10 = 12/20 we assume a misconception regarding adding fractions, yet this is how we add test marks.

While recognising the importance of children's first conceptions or, as she calls them, pre-conceptions, Driver (1985) has claimed “they are very tenacious and resistant to extinction, and that the unlearning of pre-conceptions might well prove to be the most determinative factor in the acquisition and retention of subject matter knowledge”.

Context

Context is emphasised by Confrey (1994) who argues for a less incremental view of knowledge development, and says “within such a view, context does not simply create the purpose for the goal directed activity, but creates participation structures that encourages increasing awareness of complexity”. In terms of prior ideas, knowledge schemas, and the role of language, practical and familiar contexts obviously provide reference points for learners as well as starting points for teachers.

Participation

Salomon and Perkins (1998) taking a social constructivist view, have 'mapped the territory for learning' as a participatory process and listed six types of social learning:

1 Active social mediation of individual learning (cognitive)
2 Social mediation as participatory knowledge construction (situative)
(not so much socially facilitated acquisition of knowledge and skills but participation in social process of knowledge construction - joint construction of knowledge and skills over existing social systems not individual appropriation)
3 Social mediation by cultural scaffolding (with artefacts such as books, videos, language)
4 Social entity as a learning system (collective learning - organizations, teams, etc)
5 Learning to be a social learner (metacognition, learning to learn)

6 Learning social content

These six types of social learning need to be considered in learning and opportunities will need to be provided by teachers to ensure that these type of learning are facilitated in classes.

Implications for Teaching

Much that has been said by people professing to be constructivists may have only tenuous links with constructivism, and, much of what is argued as implications of constructivism could be justified on the basis of other theories about learning. An example of this is cooperative learning which many constructivists see as important in constructivist teaching; but writers in the 80s simply saw it as a way of facilitating effective learning; and now one could argue for it in terms of 'social and cooperative skills' which are endorsed by the curriculum framework document (Ministry of Education, 1993).

While constructivism is a theory about coming to know, there seems to be a need to emphasise that the construction of knowledge is assumed to occur in every learning situation and in spite of teachers. For example lectures provide sensory input and if learners engage with the ideas presented and construct meaning from them, then the lecture may be an efficient way of introducing ideas and promoting the construction of knowledge. In spite of this, most constructivists would agree that the traditional transmissive models of teaching do not promote the interaction between prior and new knowledge, nor the conversations and interactions that are needed for internalization and deep understanding (Richardson, 1997).

The seven implications for learning - personal construction, prior learning, role of language, accepted views, theories are provisional, context, and participation - have implications for teaching. Some of these will be discussed here, then I will look at some constructivist *teaching approaches* and the emerging *role of the teacher*.

If teachers are to facilitate the personal construction of knowledge then existing power differences between students and teachers and the authority of textbooks both need recognition (Richardson, 1997). Teachers need to be empowering rather than being authoritative and validating thinking. A consequence of this is that students must take more responsibility for their own learning.

Littledyke (1998) argues that children come to learning with a range of life experiences and previous school experiences and that teachers need to find out what

the children know. The differences in personal construction from these experiences means that different groups of children will need different experiences to extend, confirm or challenge their knowledge schemas. They may also need a range of related experiences to help them refine and clarify concepts at particular levels. While the teacher is facilitating this they need to keep in mind the core notions towards which the learning activities are directed. Finding out something about the prior ideas of children is part of formative assessment (which is really a part of teaching rather than part of assessment). These prior ideas (alternative conceptions and misconceptions) should not be seen as something to be challenged directly, but as starting points from which to build more socially accepted models (Howe, 1996).

All thought is mediated by language and teachers need to be aware of the way that children's concepts are linked to their developing understanding of words (Howe, 1996). Because language and culture are intertwined, the acceptance of the role of language in learning implies that learning is also dependent on culture. While social interaction, communication and discussion are valued within the learning process, the way that learners of different cultures view their teachers (as respected elders, or as authority figures) will influence the forms of interaction that their culture accepts.

The theories that learners construct are provisional. This means that teachers need to understand some of the possible alternative viewpoints that might emerge at some time while a particular concept formation is occurring. An extreme example from the teaching of science involves considering moving something across the table - learners may exhibit the 'naive' view (it moves only while it is pushed), a 'Newtonian' view (it moves at a constant velocity unless a force is acting upon it), or a 'relativistic' view (which suggests that velocity changes are not merely dependent on forces but also on the speed of the object). To understand and facilitate the learning process the teachers' subject knowledge is important as they help guide students towards socially negotiated truths and they must have a good understanding of what these are.

Teaching approaches

Numerous teaching approaches using constructivist ideas have been developed.

The problem-centred model (Wheatley, 1991) has three components:

- the teacher selects tasks which have a high probability of being problematical for students;
- the learners work on these tasks in small groups. During this time the teacher facilitates collaborative work as a goal as the social interaction that occurs is seen as beneficial;

- The class is reconvened as a whole for sharing. Groups present their solutions to the class, not to the teacher, for discussion. The role of the teacher in these discussions is that of facilitator and every effort is made to be non-judgemental and encouraging. This stance is used so that students are empowered and in control of their learning.

In interactive teaching (Biddulph and Osborne, 1984) the teacher endeavours:

- to become more sensitive to learner's ideas and questions and provide exploratory experiences from which the learners will raise useful questions and suggest sensible explanations;
- to carry out with the whole class or with groups of learners, activities to focus on the questions and ideas that many of the learners had;
- to act as a team research leader with the class, to help them plan and carry out their own investigations into their questions, and to help them draw sensible and useful conclusions from their findings. This requires the teacher to develop the skill of interacting with the learners to challenge, modify and extend their ideas, instead of providing 'right' answers and leaving the students to make sense of their experiences.

Driver and Oldham (1986) suggest that in constructivist teaching we need five components:

- orientation (to arouse interest and curiosity);
- elicitation of ideas (to help children clarify what children think);
- restructuring of ideas (to encourage children to clarify and share ideas, to expose them to cognitive conflict situations, to facilitate construction of and to evaluate new ideas);
- application of ideas (to help children relate what they have learned to their everyday lives);
- review change in ideas (to compare with previous ideas).

Wood, Cobb and Yackel (1995) emphasise class discussions and small group collaborations as constructivist learning opportunities. They stress the value of learners being given opportunities to explain and justify solutions; to listen and try to make sense of explanations given by others; and to indicate agreement, disagreement or failure to understand the explanations of others.

Role of the teacher

In these and other 'constructivist' approaches there is a role shift for the teacher which moves them from 'sage on the stage' to 'guide on the side'. This shift is likely to involve:

- finding appropriate challenging problems and learning activities;
- negotiating the details of what is to be taught;
- valuing the learners' ideas and their autonomy;
- emphasising cooperation in learning;
- encouraging communication as a form of social interaction;
- interacting with what-if questions and non-judgemental statements;
- trying to find what is going on inside the heads of learners rather than relying on their overt and often superficial responses;
- taking an interest in the errors (alternative conceptions) which may throw light on how the learner is deviating from the teacher's intended path;
- providing opportunities for learners to reflect (and develop other metacognitive skills);
- helping the students make connections by linking what is being taught with prior knowledge and experiences, with other parts of the subject, with other subjects, and with life outside school;
- accepting the notion that learning is still developmental, and that children's learning may differ with age as their thinking is constrained because certain higher intellectual functions including awareness of mental operations are not available until adolescence (Vygotsky, according to Howe, 1996);
- allowing children time to think through the implications of their findings in lessons - accepting that while construction of meaning is an active process which may lead to conceptual change, this may not lead to a change in belief (or to action); and
- paying attention to learning environments that are conducive to children constructing knowledge in social settings (Wheatley, 1991), perhaps including computer environments.

Implications for Curriculum

As I mentioned earlier, New Zealand curricula at national and classroom levels have been dominated by behavioural objectives for the last three decades. National curricula were structured as a progression of objectives and in planning lessons teachers were exhorted to start with behavioural objectives. Before constructivism this was criticised by Stenhouse (1975) who objected to the (behavioural) objectives model for curriculum in that it mistook the nature of knowledge. He suggested that knowledge is primarily concerned with synthesis and the analytic approach implied in

the objectives model readily trivializes it. This objection had considerable strength when curricula were dominated by behaviourism and little emphasis was put on synthesis, but is even more relevant when learning is viewed as a constructivist process.

With notions of synthesis of knowledge one can also raise the interesting question about subject boundaries. Lawton (1975) for example has expressed concern about the division of knowledge into subjects and fields, that the only reason for this was the interests of those in control of education. He also suggests that subject barriers are arbitrary and artificial. There is no certainty that the accepted division of knowledge into subjects and fields answers the needs of students.

I would suggest that Lawton's criticisms are valid not only across subject boundaries, but are also across topic boundaries within subjects. As well, as we come to recognise the cultural aspects of knowledge construction, we see the traditional division of knowledge is an artefact of the hegemony of what might now be called Western European thought.

From a behavioural viewpoint, knowledge was broken into a series of goals or objectives that were specific and discrete. These goals were sequenced into what was seen as natural progressions or hierarchies (logical or psychological) and these became the basis for the curriculum. The objectives were then taught in order with the belief that each objective would be mastered by a majority of the students. The organisation of the objectives for learning might be represented by Figure 1 with the content of each objective being represented by a circle and the arrows suggesting the progression.

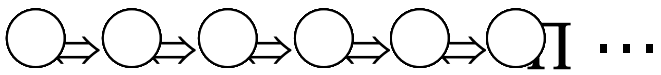

Figure 1: A behavioural organisation of knowledge

With constructivism it is convenient to think of a knowledge schema (a network, a graph, or a concept map). The facts, concepts, skills and procedures might be thought of as the circles (see Figure 2) while the lines joining the circles in the figure represent the relationships between them. These relationships might be strong, weak, or tentative. They might be uni- or bi-directional, and some may not yet exist. Using this metaphor for knowledge one can think of learning as a process of adding nodes to a particular schema, strengthening links between nodes and discarding incorrect ones, and making more links so that more ideas are connected. With this metaphor mastery

is not an adequate notion because an individual's networks will be unique to the individual (though it will include many commonalities or shared understandings), and because each network will be continuing to change as a result of a learner's experiences over time.

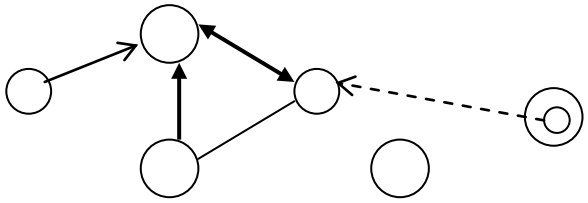

Figure 2: A constructivist knowledge schema

This schema differs from the behavioural one in a number of important ways. Firstly, it moves the emphasis from the 'analysis' (of the subject into objectives) to a 'synthesis' of the subject where knowledge is seen more holistically. Secondly, knowledge is thought of as a network of related ideas rather than a predictable linear sequence. And thirdly, when one considers what one learns, the relationships (or arcs) between the facts, concepts, skills or procedures (or nodes) are just as important as the nodes.

Such a connected network ties in with the ideas of connected (rather than separated) knowledge from the gender literature (Belenkey, Clinchy, Goldberger & Tarule, 1986) and this in turn has been received favourably by a number of indigenous cultures who also view knowledge in a connected way.

Teachers need to know what they intend to do throughout the year and in each lesson, hence national and/or classroom curricula still need to exist. For me constructivism implies that a change is needed from well-defined (behavioural) learning objectives which one could easily test, to the provision of broader learning objectives. These would provide direction but allow for flexibility and negotiation of the curriculum which is suggested by some of the constructivist teaching approaches. Such negotiation would reflect what students already know and where they are coming from; it will assume that they will construct ideas and seek their own solutions rather than follow a path determined totally by the teachers; and will accept that the outcome of the learning will vary for different learners. With these broad objectives the teacher is still in control of the main thrust of the lesson but details will vary as the teacher responds to the learners' needs.

Another change in curriculum relates to context. The curriculum needs to be developed with regard to the familiar contexts to which the students are able to make links. These will vary for different languages, cultures, socio-economic situations, and

groups studying different subjects. It will need to take account of the range of interests of the students.

A third change in curriculum relates to ensuring that learning activities provide opportunities for active participation by the learner and do not rely on passive transmissive modes of interaction. This is often regarded as peripheral to the curriculum which was formerly viewed as the list of things to be taught, rather than suggestions on teaching, but it fits with the definition of curriculum that talks of 'all planned activity for the school'.

To satisfy these three changes in curriculum a general document might be acceptable. However, for teachers a more useful focus might be on good learning activities within a general framework. A guide for the selection of these activities is provided by Ahmed's (1987) criteria, he suggests that a rich learning activity (for mathematics):

- must be accessible to everyone at the start
- needs to allow further challenges and be extendible
- should invite children to make decisions
- should involve children in speculating, hypothesis making and testing, proving or explaining, reflecting, interpreting
- should not restrict pupils from searching in other directions
- should promote discussion and communication
- should encourage originality/invention
- should encourage 'what if' and 'what if not' questions
- should have an element of surprise
- should be enjoyable.

In considering the traditional developmental structure of curriculum, Driver (1985) has suggested that curriculum development needs to pay attention to the structure of thought of the child and that the logical order of teaching a topic may not correspond to the psychological order of learning. She has also written of the need for activities which challenge alternative interpretations as well as confirm accepted ones. Grennon-Brooks and Brooks (1993), who support the view that learning is developmental, suggest that we look at learning as a journey rather than a destination and each step of development is a temporary stop on the path of ever increasing knowledge. This view of development however is not the traditional one, it does not assume a linear sequence or a progression through objectives, nor does it imply that one 'bit' of knowledge is totally developed before another is started.

Implications for Assessment

The behaviourist view of assessment was that only behaviours could be validly measured and therefore that assessment objectives should be behavioural ones. In discussing the priority given to such a measurement perspective Giorgi (1970) admits that the problem is that for something to be measured only its tangible aspects can be apprehended, and, as a result, the indices associated with these aspects of the phenomenon become more important than the phenomenon. He goes on to say, in the context of research, but equally important for assessment, that in the search for the measurable element one loses sight of the significance of the other aspects of the phenomenon. The non-measurable aspects tend to be discarded, and only the measurable elements are included in the investigation.

In agreeing with Giorgi, I would say that considering a knowledge schema (or web) as a way of thinking about how a learner organises their thinking should cause us to initiate a search for different approaches to assessment. Concept maps, student journals, and portfolio assessment are three approaches that might be considered.

In moving from the measurement paradigm, one obvious implication of constructivism is to increase the amount of formative assessment (before and during learning). This assessment is likely to be informal and seen as part of the learning process and its purpose is to inform the teaching and learning process. The focus of this form of assessment would be to:

- find what learners bring to the class in terms of their interests, prior knowledge and ideas, alternative conceptions and likely questions;
- get an indication of how their new knowledge and their prior knowledge are interacting;
- find what the learners are thinking rather than their overt responses, that is their constructed meanings rather than whether they have the 'right' answer;
- identify differences between the learners' understandings and that of the teachers (the intended understanding).

Summative assessment (after learning) is usually more formal and its purpose relates to reporting and awards. The focus of this would be to:

- measure understanding rather than training, for example measure the ability to use simple ideas in unfamiliar situations rather than the ability to recall facts or use procedures in set and familiar situations.

If summative assessment focuses on measuring conceptual change, that is value-added or before compared to after, then it will be problematic - particularly if the curriculum

has been freely negotiated. Even when activities and problems are chosen to cover specific content areas, if strategies are used that encourage constructivist learning then difficulties are likely to occur. Jaworski believes that activities are developed to bring pupils up against particular concepts and might be measured against their success in this. Too strict an adherence to the aims might restrict the outcome, a more open-ended approach in practice may prevent the aims ever being achieved. However, testing for standardisation can lead to teaching for the tests, so that pupils can be seen to be successful (Jaworski, 1988).

Another consideration in a constructivist setting when students are to take more responsibility for their own learning is to develop learning-to-learn and self-assessment skills. This involves questioning, planning and sharing skills for learning. For self-assessment it implies being able to: identify what one is learning and when one is learning, reflect on one's learning, compare self-assessment with that of others, and compare one's own knowledge with that of others to appreciate that other possibilities exist.

Implications for Research

There are many ways one can think of research paradigms. Popkewitz (1984) talks of three - empirical-analytic, symbolic-linguistic, and critical. Other words associated with these three paradigms are drawn from Cresswell (1994), Lather (1992) and Kuhn (1970) and given in Table 2.

Table 2: Research Paradigms

empirical-analytic:	scientific, quantitative, positivist, objectivist
symbolic-linguistic:	humanistic, qualitative-interpretive, constructivist, relativist/subjectivist
critical:	empowerment, emancipation, qualitative-political, praxis-oriented

If one accepts constructivism then, regardless of the paradigm one works in, one's results would be subjective. This is because the researcher decides what question to explore, what approach to use, what data to collect, and how the data will be interpreted. These choices depend on the researcher's prior experiences. In this situation it is reasonable to use the personal "I" in reports rather than the neutral "the researcher" as "I" acknowledges the subjective nature of the research. It is also important to expose the background, assumptions and influences of the researcher in the same way that one would expose a questionnaire or other research instrument as the researcher is now a research instrument.

Implications for Teacher Education

If constructivism provides a better explanation of the learning process than other theories, and if it implies different teaching strategies, then teacher educators in pre- and in-service work must ensure that their students are introduced to it through consideration of the ideas and through modelling. However, prospective and existing teachers bring robust prior knowledge schemas based on their prior experiences of more traditional learning and teaching to their teacher education classes, so the ideas of behaviourism are not likely to be given up quickly and attempting to move the students' thinking will be a difficult task. In addition, the various forms of constructivism will probably need to be discussed as different students are likely to will feel more comfortable with different variations.

Criticisms of Constructivism

Constructivism as an educational theory does have limitations. It provides a way of explaining how people learn, but it has been criticised as follows.

Firstly the word constructivism has as unfortunate connotation, for many it seems to conjure up ideas related to building - starting with foundations, well defined pre-existing pieces, an orderly building programme, and so on. Such a building metaphor probably fits better with behaviourism than with constructivism.

Secondly, there has been a lack of models for constructivist teaching, some teachers interpreted constructivist teaching only as individual discovery, while others believed that students construct learning in all situations and no changes to teaching were needed. This is hardly a criticism when the theory has always purported to be about learning rather than teaching, and it is less valid now that more of the implications to teaching are emerging. Related to this lack of teaching models is a lack of curriculum and assessment models, and this has meant that teachers are subjected to mixed messages when they talk about constructivist learning but are presented with curricula and assessment in behaviourist formats. As I have shown, many educators are developing implications from constructivism that combat this criticism.

Thirdly, there is a lack of a critical dimension which means that there is no mechanism to avoid the construction of undesirable outcomes (Taylor, 1996). This seems no different from traditional learning where the critical dimension depends mainly on the teacher. An alternative approach to constructivism called "critical" or "emancipatory constructivism" has been developed by Taylor (1996) who saw the need to ensure a commitment to social change, justice, responsibility and the reduction of inequality

and oppression and to avoid the construction of concepts such as inequality, power relationships, or prejudice that many believe are educationally undesirable yet are still able to be learnt within other forms of constructivism. This seems to me to be paradoxical when constructivism was intended to explain all learning, regardless of the values that we may ascribe to particular content.

Fourthly, and related to the lack of a critical dimension, there is an undue influence in education and in what constitutes knowledge by the dominant culture which is currently the white male middle class (Zevenbergen, 1996). The impact of these inequitable influences of race, gender, and power or privilege are seen in terms of what has been defined as socially acceptable knowledge and these views are typically accepted by teachers, schools, and the education system. This concern about the hegemony of the dominant culture is relevant to theories other than constructivism and could perhaps have been anticipated when the emphasis moved to social construction or enculturation. While the consideration of prior knowledge in constructivism and the emergence of cultural studies within subjects (such as ethnomathematics) might suggest that this domination is being reduced - in fact there seems to be little evidence of change and students from different groups who see things differently and do not construct the 'right' knowledge continue to be marginalised and excluded in the educational system.

Fifthly, constructivism seems to be concerned only with cognitive knowing. It does not explain unformulated or subconscious knowledge, it does not consider how things might be known intuitively or instinctively, and it does not consider how emotions are constructed or their role in learning. It does not explain to me how a newly-hatched turtle has learnt that it must immediately head towards the open sea and this means that there may need to be a consideration of other forms of learning such as 'instinctive' or 'hard-wired'. To some extent an "enactivist" theories which is a development from constructivism, does consider this sort of learning - it differentiates between formulated learning which involves cognition and unformulated learning which is to do with the individuals' relationships with their contexts, but it does not differentiate between knowing and living (Davis, 1996).

Sixthly, there do not seem to be explicit links made between constructivism and the learning theories that brain-science or neural biology offer. Constructivism has always been offered as a theory based on educational research and philosophy but as the work in neural biology and evolutionary learning theories progresses, one might hope to see a coming together of biological and educational theories. The work of Maturana and Varela (1987) and of Davis (1996) appear to be early moves in this direction.

Conclusion

Constructivist theories are about 'how one comes to know'. These theories are not 'true', they are not 'laws'. They have not been proved although there is considerable evidence to support the notion that they are useful. The theories are consistent in as much as they provide a viable fit with the experiences of many people and enable them to make sense of their worlds. Like all theories, they will be useful if they explains what they purport to explain and if they provides a sensible basis for planning. They will be replaced by new theories if the new ones provide more useful explanations or a better basis for planning.

I would hope that we all encourage existing and prospective teachers to consider constructivism while at the same time we remain vigilant in looking for better theories.

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