From Misconceptions to Constructed Understanding
The Fourth International Seminar on Misconceptions Research (1997)

Article Title: Implications For Teaching Derived From A Constructivist-Based Model Of Learning In Science Classes

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Keywords:
General School Subject:
Specific School Subject:
Students:

Macintosh File Name: Appleton-Constructivism
Release Date: 10-2-97 A

Editor: Abrams, Robert
Publisher: The Meaningful Learning Research Group
Publisher Location: Santa Cruz, CA
Volume Name: The Proceedings of the Fourth International Misconceptions Seminar - From Misconceptions to Constructed Understanding
Publication Year: 1997
Conference Date: June 13-15, 1997
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

subscription to the collection or joining the Meaningful Learning Research Group.

IMPLICATIONS FOR TEACHING DERIVED FROM A CONSTRUCTIVIST-BASED MODEL OF LEARNING IN SCIENCE CLASSES

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Date Completed: 5-28-97.

A paper presented at the symposium *From Misconceptions to Constructed Understanding*, at Cornell University, Ithaca, NY, June 13-15, 1997.

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ABSTRACT

While cognitive and social constructivism have at times been portrayed as competing paradigms, some authors such as Cobb (1994) have suggested that they are different ways of looking at the same thing. In an earlier paper, aspects of both cognitive and social constructivism were incorporated into a model used to analyse and describe student learning in science classrooms (Appleton, 1997). The model has subsequently been revised and has been used to draw implications for the teaching of science. In this paper, key elements of the model are explained, and how each may be used to inform and shape science teaching is explored.

INTRODUCTION

For some years now, I have been working on simple ways to portray the essential elements of prevailing theories related to the learning of science in school settings, to provide useful guidance for my own thinking about teaching science and to find a way of helping teachers come to grips with ideas about learning and their implications (Appleton, 1993a). My personal journey appears to reflect that of many others and the changing emphases in the literature about learning in science. My journey began with a largely cognitive constructivist learning model (Appleton, 1989), which was influenced considerably by Piagetian notions of disequilibrium (1978), and my involvement in components of the Learning in Science Projects, such as reported by Osborne and Freyberg (1985) and Biddulph and Osborne (1984). Since then I have become increasingly aware of the significance of social and cultural influences in learning science such as expressed by Driver, Asoko, Leach, Mortimer, and Scott (1994), and have sought to incorporate them into my earlier ideas (Appleton & Beasley, 1994). Like Cobb (1994), I do not see these as two irreconcilable ways of viewing the world, so have tried to develop ways of somehow bringing together important elements of the cognitive and social constructivist viewpoints. I consider this particularly important when trying to help busy teachers review their own practices in the light of contemporary developments. In my experience, they do not want to be bothered with alternative theories, but want concise and helpful ideas which they can examine critically. My latest attempt to pull together ideas which might be useful for teachers, which focuses on a descriptive model of learning, is portrayed in Figure 1.

Diagrams and Models

Before progressing, I should mention my purpose in using a diagram to portray the model, and what the model represents. My use of a diagram may be part of my way of representing the world; a cognitive crutch which I find helpful and hopefully others find helpful as well. I also feel that a diagram highlights essential ideas and shows relationships between them, however, imperfectly. The model itself is essentially a descriptive, simplified and rationalised representation of how conceptual learning might occur in science classroom contexts. In it there are elements of both cognitive and social constructivism. In simplifying the diagram, much is omitted, yet its components provide a stimulus for considering more fully the implications of each.

One of my main objectives in representing conceptual learning in this way is to find a means of helping teachers understand current ideas about learning in science which also provides a pointer toward pedagogy. This is not to suggest that there is any one “right” pedagogy for teaching science, but that there are many alternative ways of teaching for which knowledge of conceptual learning can provide guidance when making choices. I have found that, in teacher education contexts, many teachers struggle to come to grips with the key ideas in cognitive and social constructivism in the time available to them, and therefore are not readily able to use them to guide their science teaching. Just as students have difficulty acquiring and relating science ideas to everyday life, many teachers have difficulty with new ideas about learning, and how to use them in their own practice. I believe it is my task as a teacher educator to help teachers do this, just as Driver, Asoko, Leach, and Scott (1995) suggest that teachers need to provide considerable assistance as they enculturate students into the world of science. I have found this model particularly helpful in this respect when working with teachers, especially when time is a constraint.

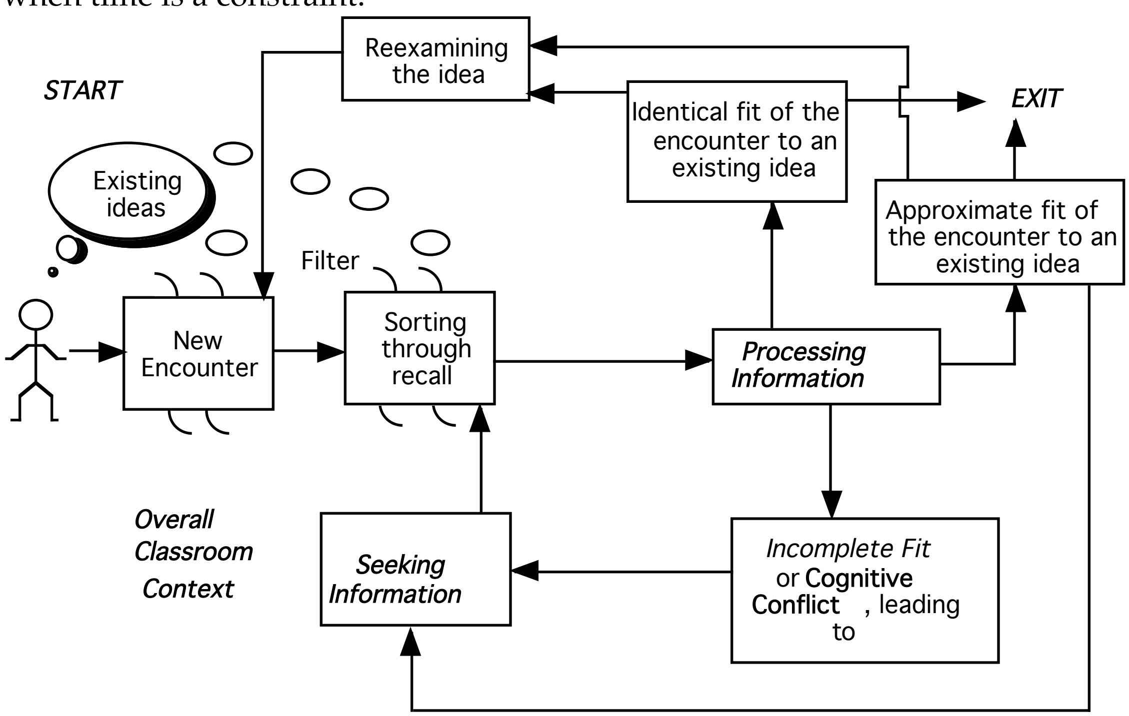

Figure 1: A Descriptive Model of Learning in Science

The model had its origins in a predominantly Piagetian (1978) view of constructivism (Appleton, 1989), with considerable emphasis on cognitive change via the ideas of equilibrium, disequilibrium and accommodation, though I found it expedient to put aside Piaget's emphasis on developmentalism. It underwent further development (Appleton, 1993b) using the ideas of authors such as Osborne and Wittrock (1983), Claxton (1990) and von Glasersfeld (1989). I have since come to refer to this view of constructivism as "cognitive constructivism" because of its emphasis on the internal cognitive functions of the learner, and to more clearly distinguish this view of constructivism from social constructivist ideas emerging particularly from Vygotskian thinking (Vygotsky, 1978; Wertsch, 1985). After several revisions and evaluations (Appleton & Beasley, 1994), the model has become less reliant on cognitive constructivist ideas, and more dependent on an understanding of the influence on learning of the social context and social interactions (e.g. O'Loughlin, 1992). The model has been evaluated in several science classes (Appleton, 1989, 1993b, 1995, 1997) and revised according to the data obtained about students' cognitive responses during the lessons. The most recent version described here has been simplified to more readily convey the key constructivist ideas inherent in the model, and the teaching implications which may arise.

In this paper I therefore examine each component of the model in terms of both cognitive and social constructivist ideas, and then look at implications for teaching which I see as emerging. These implications are not necessarily new or different, but provide a form of a checklist or reference for guidance. Nor would I claim that the implications are unique to this theoretical framework. Good science teachers may well find that they already use a number of these teaching ideas. However the model does provide an overall coherent view of conceptual learning which can be used to inform teaching.

AN EXPLANATION OF THE MODEL

The model focuses on the individual as part of a science class group partly because of the history of the model's development, and partly because both cognitive and social constructivist theories provide insights into individual students' conceptual learning as they participate in science classes. My discussion of the model commences at the **Start**, although in a social context it may be debatable where the "Start" is. I will examine each component of the diagram in turn (highlighted in bold), provide further detail omitted by model simplification, outline cognitive and social constructivist perspectives of that part of the model, and finally suggest some pedagogical points arising from these.

Existing Ideas

Learners approaching a learning task bring with them all previous experiences organised in the mind as sets of ideas, structured as schemes. This arrangement of schemes is sometimes referred to as a cognitive structure. The schemes are developed through a combination of experience with the natural environment, language, and social interaction. They are shaped by the culture in which each learner lives. Since schools have their own culture and social rules, specific schemes are developed for the school culture and classrooms. The schemes may be fragmentary or partially developed, and sometimes might include what experts in the field would consider to be misconceptions. Some school schemes may be separate from schemes developed through everyday experience, distinguished largely by their respective social contexts. That is, schemes tend to be context or even situation specific, but can develop into more general schemes as expertise in a field develops (Claxton, 1990).

Schemes are also considered to include skills and emotions (Claxton, 1990), so this part of the model also includes how each learner might be feeling at the time of the learning task, such as anger from an argument at home, a desire to achieve and do well at school, a fear of failure in science, or boredom and feelings of alienation from school. A key component is also the cultural and language base/s in which a learner feels comfortable and can operate without loss of self-esteem. If this differs from the dominant cultural/language base practised in the classroom, the learner is likely to experience, at least, feelings of insecurity (e.g., Corson, 1993; Gee, 1990; Lankshear, 1996).

Implications for teaching. The teacher becomes acquainted with the cultural groups in the class. Knowledge of learners' cultural orientations helps the teacher plan to include all learners. The teacher identifies the learners' ideas about the planned science topic. This can be done using individual or group interviews; concept maps; surveys; discussion in small or large groups; or writing in structured genres, or in unstructured forms like journals. Such information can serve as a basis for planning the curriculum content and/or how to interact with learners. The teacher is also sensitive to the learners' body language to obtain clues about their current emotional states.

New Encounter

The encounter is a specific learning experience or task, usually planned for by the teacher. On some occasions it may be an opportunistic event which the teacher capitalises on. It occurs in a school and specific classroom social context, embedded within a teaching approach selected by the teacher. Depending on the teaching approach, learners may be directly involved with the encounter individually or in small groups, or indirectly as part of the whole class (Appleton, 1993b). Each learner attends to it because of social expectations within the classroom context, unless emotional factors distract the learner. Note that the model is limited to learners who choose to attend, even though some classroom participants may choose otherwise. The learners' perceptions of the encounter experience and their expectations of its outcome are in part determined by the cues provided by the physical and social context in which it occurs (Osborne & Freyberg, 1985). For instance, perceptions and expectations for an encounter experienced during a field trip near a creek would be different from one experienced in the classroom, the library, or a laboratory.

Implications for teaching. The new encounter is motivating, interesting, provides a link to past experiences, and preferably includes some form of first-hand exploration; though this is not always possible or appropriate. Instead, it may involve some structured social interaction in small groups or with the teacher. It may be selected to provide a challenge or contrast to the learners' ideas, particularly if misconceptions were earlier identified. In this case it would lead to an **incomplete fit** for most, if not all, learners. The new encounter forms a part of a carefully selected sequence of experiences, the chosen teaching approach, which are designed as a scaffold[1] (Appleton, 1996) to guide the learners towards the goals determined by the teacher. It is chosen using the teacher's foreknowledge of the learners' general interests and expectations of school science, including gender considerations. It occurs within the established social climate of the classroom, and is therefore compatible with it and the learners' expectations and experience. Encounters which differ markedly from the classroom social norm may result in unexpected social behaviour. For example, providing an encounter involving hands on work in small groups to learners who have never experienced this before may result in their being uncertain of social expectations, and consequently using behaviours which the teacher considers inappropriate.

Sorting Through Recall

Particular aspects of the encounter may be noticed by each learner, and other aspects missed. The learner makes sense of the encounter by drawing on past experiences and any related explanations which seem to the learner to be relevant. This involves a search through schemes for one which seems to fit the circumstances best, that is, a sorting through memories recalled. Learners take cues from the context of the encounter, such as unit and lesson structures and teacher comments, to aid in this search. Cues from other learners may also be used. These are represented in Figure 1 as the **filter**.

Implications for teaching. The teacher is conscious of the cues she/he is providing within the science unit and particular lesson, and indicates to the learners any which might be confusing, or which should receive special attention. Learners less adept at noticing such cues may be helped if the teacher explicitly highlights them. The teacher uses techniques during the lesson to find out what schemes the learners are using to make sense of the encounter, which alerts him/her to possible false trails the learners may be

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1 Scaffolding occurs when a tutor (either adult or capable peer) helps the student build an extension from an existing schema into new cognitive territory through a series of small steps which the student would not be independently capable of. It involves developing a mutual understanding of each other's ideas as the extension is constructed. Eventually the tutor can withdraw, leaving the student under full control of the newly constructed extension.

following. For example, this might involve learners talking about the encounter, either in small groups or in whole class discussions.

Filter

When a new object, event, or information is encountered, each learner may select to attend to particular aspects of it and to ignore others. This selection may be by chance, by what is spectacular and attention-getting, or by the learner’s expectations of the lesson. Further, learners experiencing some emotional upset may miss most of the encounter because they are unable to attend to it fully. Learners in early puberty may also be distracted by members of the other sex, so they attend more to them or their own social behaviour than the encounter. The classroom context of the learning experience (Claxton, 1990) influences which ideas of the learner's cognitive structure are used to interpret the experience, both in terms of which sensory input are attended to, and which memories are activated in order to construct meaning for the experience (Osborne & Wittrock, 1983). The social setting of the classroom makes those schemes associated with schooling most likely to be called upon first, so everyday schemes may not be selected to help interpret the experience. A consequence may be that schemes associated with schooling develop independently from those associated with everyday schemes (Claxton, 1990).

Implications for teaching. Learners’ expectations of the lesson can be better aligned with those of the teacher if a brief statement of the lesson goals and an overview is provided early in the lesson (Ausubel, 1968). Ownership of the task by learners also raises their expectations of the lesson. Ownership usually increases when learners are able to make real decisions about the curriculum and their involvement in its implementation. The teacher therefore employs teaching approaches which allow for and encourage learners’ ownership of the task. The teacher also encourages learners to compare school work with everyday events to make it easier for them to generate cross-links to everyday schemes as well as school-based ones.

The teacher is conscious of the social setting of the lesson, both in terms of the teaching strategies being used, and the emotional undercurrents among the learners. Sensitivity to the former may provide a more productive working climate. For example, a highly authoritarian strategy used with a group of teenaged rebellious males is certain to trigger rebellion and take attention from the task (Shymansky, 1978). Awareness of any emotional undercurrents allows compensatory action to be taken should any problems emerge.

Processing Information

This may occur at two levels. In *Surface Processing*(Biggs & Moore, 1993) there is a focus on words, concrete aspects of the encounter, and rote learning. It involves a minimum of mental processing of the available information into the cognitive structure. *Deep Processing* involves trying to reach understanding and make sense of the encounter by relating it to remembered schemes, using thought experiments, or generating analogies. It takes considerable effort by a learner to ensure understanding is complete, to restructure old ideas, or to incorporate some new ideas into existing schemes. A similar distinction has been made by Bereiter and Scardamalia (1993), who compare two approaches to learning, a "Best-Fit" strategy and what they call Progressive Problem Solving. In the former, the learner tries to fit the new encounter into existing ideas and rules, and chooses a "best-fit" scheme to operate with, even if the degree of fit is not particularly good (see also **Approximate Fit** below). This seems to involve selecting those aspects of both the encounter and the recalled cognitive scheme/s which have similarities, and focusing only on the similarities. By comparison, Progressive Problem Solving is a deliberate attempt to note differences and resolve them, constructing a new scheme if necessary. They closely link this latter process to creativity. Bereiter and Scardamalia's descriptions of approaches to learning seem to have many similar characteristics to the distinctions between surface and deep processing.

Which level of processing occurs depends on both the learner and the context. Learners who lack the cognitive skills to engage in deep processing must use surface processing -- they have no option. If learners have the cognitive skills to engage in deep processing, then they may choose the level most appropriate to the circumstances and their own expectations of the lesson (Biggs & Moore, 1993). For example, if their expectations are that the lesson is important for an imminent test involving mainly recall, then surface processing will probably be used. The level of processing will also be influenced by the social context, the teaching strategy, and the learners' emotional state (Appleton, 1993b). For instance, learners who have experienced repeated failure in science would not consider it worth the effort to engage in deep processing. Also, if the teacher's questioning involves a rapid series of recall questions, learners will be effectively prevented from engaging in deep processing. Sometimes both surface and deep processing may occur together, where aspects of the encounter are deep processed, and other aspects are surface processed (Biggs & Watkins, 1993). For example, this may occur when new terminology is being introduced. The words are rote learned, but the principles associated with them are deep processed.

The description of the processing of information so far has emphasised the learners' internal cognitive processes, but which of these occurs for any particular learner is determined largely by the cultural and social context. For example, cultural and language factors, where English is not the learners' first language, may predispose them to using surface processing initially followed by later deep processing (Biggs & Watkins, 1993). The social environment of the school, and the extent of the learners' enculturation into the school social setting will also influence the learners' desire to achieve, and whether they consequently use surface or deep processing (Biggs & Moore, 1993). Further, the social environment created in the classroom by teacher and learners has considerable influence over whether surface or deep processing occurs. This happens at both a general level of overall classroom climate created by teacher/learner negotiation (Edwards & Mercer, 1987; Edwards & Westgate, 1987), and at a specific level created by the teaching strategy employed for any particular science lesson or segment thereof (Appleton, 1993b).

Of final significance to processing information is the nature of the verbal transactions which occur in the classroom. It seems that, when information is mediated socially, the nature and quality of the social transactions can have considerable influence on the cognitive outcomes for learners (e.g., Fleer, 1992; Woodruff & Meyer, 1997).

Implications for teaching. If the teacher's purpose is for the learners to engage in deep processing, then suitable teaching strategies and techniques are chosen both to allow this to happen, and to facilitate it. This is just as crucial at a day care centre as it is in a senior high school class. Key aspects of encouraging deep processing are structuring lessons and interacting with learners. Principles of scaffolding (Bruner, 1985, 1986) in both a structural and a verbal sense are relevant. Strategies and techniques for enhancing deep processing include asking divergent questions (Gega, 1991), using long wait times (McGlathery, 1978), small group discussion (Cazden, 1988; Woodruff & Meyer, 1995), judging conclusions on the basis of the evidence and consensus (Meyer & Woodruff, 1994), and engaging learners in tasks which give them some level of ownership (Osborne & Freyberg, 1985). It may also be possible to provide explicit instruction to develop learners' ability to use deep processing cognitive strategies, in a metacognitive sense (Baird & Northfield, 1992; Baird & White, 1996).

However, the teacher is also sensitive to those occasions when surface processing is the most appropriate method of engagement with the encounter. In these cases, instruction in the use of memory aids such as mnemonics would assist learners. The teacher is also sympathetic towards those learners who resort to surface processing as a survival technique, where, because they are unable to keep up with the lesson pace, they rote learn fragments in the hope that they will be able to deep process the material at a later date. That is, if the lesson progresses too fast, some learners may not be able to sustain the level of deep processing, and get left behind. The only course of action left to them is to use surface processing. This is often a strategy employed by learners whose first language is not english (Biggs & Watkins, 1993).

The whole area of cultural and social effects on information processing demands great sensitivity of teachers, where they are firstly aware of the social events and interplays in the classroom, and secondly are able to make decisions about social responses and pedagogy based on an appreciation of the social context and its likely implications for learning. An example may clarify this. A junior high school science teacher may have a preference for text book-based teaching and verbal explanations. In a group of mainly upper middle class caucasians, this may result in a fairly productive class atmosphere where the learners achieve satisfactory results. In contrast, it may be a disastrous strategy to use consistently in a group of learners drawn from a mixed ethnic area with high unemployment, and result in disruptive behaviour and poor learning. While this example involves a complex interplay of motivation and social expectations, clearly emphasis on written and verbal learning contexts favours those who can deep process effectively in those contexts, and creates problems for those who cannot or who are not prepared to expend the effort to do so.

Degree of Fit

As a consequence of processing information, there are three possible levels of fit of each learner's past experiences and related explanations drawn from memory, with characteristics of the new encounter. Firstly, there is an **identical fit** if his/her perceptions of the encounter are completely explained by the remembered scheme(s). This may include some small addition to what is already known, so that a scheme is extended slightly. The recalled memories increase in status so that previous learnings are reinforced (Osborne & Wittrock, 1983). As far as such learners are concerned, the lesson is finished (**Exit**). This is not a problem if the reinforced learnings conform to the scientific explanation. However, if the learners have not noticed some key aspect(s) of the encounter, inappropriate schemes may be used to interpret it, compared to those which may have been used had the key aspect(s) been noticed. Such learners would therefore leave the learning experience with an inappropriate explanation for the encounter, resulting in an invalid explanation being reinforced or extended.

Secondly, if learners select from memory an explanation which superficially fits the object or event without checking for inconsistencies, this results in an **approximate fit**. That is, a vague answer is accepted as adequate, where near enough is considered good enough. As far as many learners would be concerned, the lesson would thus be finished (**Exit**). In this case, a wrong idea could be reinforced, or at least, the learners would have no real understanding of the encounter. Some learners would, however, recognise that their answer was vague, and may take steps to determine its validity by **seeking further information** -- possibly even suspending judgement. Bereiter and Scardamalia (1993) suggest that this strategy of accepting an idea as approximate is useful in many contexts, particularly when dealing with routine situations. However, it is not helpful in developing new knowledge and expertise.

Learners who achieve some level of fit usually seek confirmation of their idea from an authoritative person in the classroom, such as the teacher (Cazden, 1988). If the teacher does not supply this, they resort to peers recognised as gifted in science, and finally may go to a book or parents. This behaviour seems to arise from expectations associated with normal classroom social transactions (Edwards & Westgate, 1987), so could be changed if different social expectations are established as the norm in science lessons. For instance, Roth (1997) and Ritchie, Tobin, and Hook (1997) provide accounts of different forms of classroom discourse, negotiation and affirmation of learner's ideas.

Thirdly, if learners are unable to retrieve memories which explain the encounter, they would have reached an **incomplete fit** state, and consequently be in a state of cognitive conflict (Piaget, 1978). Learners in a state of cognitive conflict experience some degree of frustration or dissonance (Festinger, 1957), a motivational force which can drive them to seek a solution to the learning situation. However, if the level of frustration is too high, or if the effort to resolve the issue within the overall social context is not considered by the learners to be worthwhile (Biggs & Moore, 1993), then they may elect to opt out. (This possibility is not portrayed in Figure 1.)

Implications for teaching. The teacher takes steps to identify, for each learner, whether there is an identical, approximate, or incomplete fit. The teacher can only do this by providing opportunities for learners to express their ideas, raise questions, and nominate possible answers to questions and problems. This requires a social climate where learners and teacher may communicate freely and where learners' contributions are valued (Osborne & Freyberg, 1985). Learners who fear ridicule for giving "wrong" answers will contribute little. Small group work can be an invaluable component of encouraging learners to express their ideas and to work toward solutions (Woodruff & Meyer, 1997). Woodruff and Meyer also report that, when learners are engaged in small group investigations, inter-group interactions can play a crucial role in encouraging them to identify aspects of the work not yet resolved, and to challenge ideas being offered. While small group and whole class discussions and reporting sessions provide immediate in-lesson feedback for the teacher, information about each learner's response is not always available. On the other hand, written responses can provide specific information about every learner. However, this tends to be limited in detail and can be restricted by the learners' writing ability. It also restricts the opportunities for group discussions.

Once the learners' responses have been identified, the teacher decides what action to take, if any, for each. Fortunately, many learners respond in a similar way, simplifying the task of follow-up. For learners with an identical fit which corresponds to the scientific idea, the teacher must decide whether to provide extension work, invite them to help others, or to simply concentrate on the others in the class. For learners with an identical fit different from the scientific idea, the teacher must determine how to get them to **reexamine their idea** (see below). For learners with an approximate fit and who are content with this, a similar decision needs to be made by the teacher. For learners who wish to clarify their idea, and learners who have an incomplete fit, the teacher needs to consider **sources of information** (see below) available to the learners.

Reexamining the Idea

Learners who have effectively exited from the learning experience because of a perceived identical fit or because a vague idea is considered adequate, may be reengaged with the lesson if something occurs to cause them to reexamine their idea (Appleton, 1989). This would occur, for instance, when some social or physical event reveals an inadequacy in their idea, such that it essentially becomes a new encounter for them. Since the learners are constrained by the social context of the classroom and cannot physically leave, this may happen coincidentally; but it could also be a planned component of the teaching approach or teaching interactions.

Implications for teaching. If the teacher ascertains that some learners have developed misconceptions, or have become satisfied with a vague explanation, he/she can invite the learners to explain their ideas. This provides opportunities for their ideas to be challenged so the learners will reexamine them. Challenges may be made by the teacher (with careful wording), peers, a test of the idea using the materials, or some authority source. It may also become necessary to draw the learners' attention to a key aspect of the encounter which they have missed. The basis for deciding the validity of any idea should be a consensus reached by the group based on the evidence available. When several events related to the same scientific principle are being considered, the teacher should also insist on coherency of explanations (Meyer & Woodruff, 1994).

Seeking Information

A consequence of cognitive conflict is almost exclusively information-seeking behaviour (Appleton, 1993b; Festinger, 1957). Learners who have arrived at an approximate fit may also seek information to clarify the vague idea, or to test its validity (see above). By obtaining further information, cognitive conflict is reduced as the learner again processes information, and modifies existing ideas, extends them, or constructs new ones (Osborne & Wittrock, 1983). Information may be sought from a variety of potential sources (Appleton, 1997) by:

- exploring the materials vicariously, such as through a teacher demonstration;
- exploring the materials directly using hands on;
- using the ideas of others who are external to the classroom, such as books, audiovisual and multimedia resources, and community experts;
- using ideas from the teacher;
- using ideas from peers, obtained one-to-one, in small groups, or in the whole class;
- waiting for the answer to be revealed, if the teacher maintains control over information flow and availability; and
- using unit, lesson, and teacher structuring cues such as the topic from previous lessons, teacher actions, what the teacher says about the encounter, and what the teacher does **not** say.

Which of these information sources is used depends partly on each learner, and to a large degree on the teaching strategy used by the teacher (Appleton, 1993b, 1997). Some learners may not have the information accessing skills to use some sources effectively. For instance, the effective use of books depends on reading skills using a number of different reading styles, summarising skills, and so on. Similarly, not all learners may recognise teacher lesson cues and structuring -- particularly those from non-western cultures. The teaching strategy within the broader classroom social context, however, is the main determiner of which information sources learners may access (Appleton, 1997). For example, if the teacher uses a teacher demonstration, direct access to information via hands on investigations is not possible. Further, unless the strategy includes a period when learners may consult books and similar sources, this can only happen after the lesson. The teaching strategy also controls what is done with the information obtained -- whether it is confined to one person or a small group, or shared across the whole class.

The form of the information is also pertinent. Some information is not easily understood, let alone able to be related to the task at hand, because it is too complicated, or because it is hidden in a lot of extraneous or complex information (e.g., Purnell, Solman, & Sweller, 1992). Some learners therefore need help in identifying and accessing relevant information. It may sometimes be necessary to “translate” complex forms to simpler ones useful to learners.

Some information sources may also be privileged in particular cultures (e.g. Harris, 1984). For example, elderly males may be the traditional keepers of knowledge which is passed on verbally. Learners of a particular age and/or gender from such cultures may therefore have a preferred form of information source, and some forms may not be considered appropriate for them. Such learners are likely to bring these cultural views with them into the classroom, resulting in unexpected and inexplicable behaviours judged from a western cultural viewpoint.

A further aspect of information seeking is the social dynamic of the classroom. Information is most useful to learners if there is a publicly-agreed purpose for obtaining it which is not at odds with each learner’s private purpose (Biggs & Moore, 1993). A preschooler’s private purpose may be to please the teacher, while a Year 12 student may wish to pass the next test.

Some, such as Bereiter and Scardamalia (1993), have suggested that a valid public purpose for information gathering is to arrive at an explanation which is valid in terms of the evidence (information), and which has been agreed to by the group. This means that information from all sources, including authority sources, must be considered contestable and testable. It requires specific action by the teacher to ensure that the appropriate social climate exists for such a view.

A final consideration is the emotional state of each learner. If a learner is in emotional turmoil over some recent upset, he/she is unlikely to seek information, and may merely go through a pretence of doing so. If a learner has experienced repeated failure in science, he/she is also unlikely to seek information, apart from perhaps obtaining it directly from a peer in a simple form, for surface processing.

Implications for teaching. In planning for the unit and each lesson, the teacher considers the availability of information sources. Since some learners may access information from particular sources more readily than from others, a variety of sources should preferably be available. The suitability and complexity of the information for the age of the learners is also considered. This includes how the information may be related and applied to the task at hand, and whether help may be needed for some learners in accessing and making sense of the available information. An important issue raised by Woodruff and Meyer (1995) is *when* the scientific explanation should be made available. They suggest it should be provided only when the learners have already reached, by consensus, a tentative answer for themselves. The teacher would therefore need to plan this aspect of structuring when choosing an appropriate teaching approach. If the teacher intends to provide information him/herself, explaining it using a proper verbal scaffolding for the learners needs to be specifically planned for. Of particular consideration is the size of the group with which scaffolding will occur. It is most effective for learners when the group is small; attempting to scaffold with the whole class usually results in most learners being left behind (Appleton, 1993b).

The teacher also needs to be aware of the learners who are experiencing difficulties through emotional upset or feelings of failure. They will need special sympathy and assistance; perhaps even means of accessing the information at a later stage when they are better able to cope with the demands of the learning task. The teacher also needs to be aware of any information sources or means of accessing information not acceptable to particular cultures, to avoid causing these learners undue emotional conflict between cultural values and school expectations.

The information obtained through the above sources must then be processed by each learner, and the whole iterative process recommenced. Many cycles may be used in a lesson, until all learners finally develop a scientifically satisfactory idea, and exit with it reinforced.

Overall Classroom Context

The crucial role of the social and cultural aspects of the classroom and the wider society in which it is located, has been mentioned in each section discussed above. The main elements of Figure 1 emphasise what happens with the individual, so it is crucial to keep in mind the cultural and social bounds of each learner's actions and cognitive behaviours. A key component of this is the teacher's belief system emerging from the cultural ethos of the section of schooling to which the teacher belongs. For instance, many preschool (kindergarten) teachers retain the flawed idea from early interpretations of Piagetian thought, that learners only need to be engaged in play. A part of many primary school teachers' ethos is that the highest priority is for learners to read, write and compute, so they therefore consider that subjects such as science are peripheral, and spend all their teaching time on the "three Rs." These views change dramatically in the high school, where science is considered by teachers so important, that the delivery of a large amount of content is seen to be mandatory. All these views are flawed, but hold considerable cultural influence over teachers' actions. Other cultural influences are building and room design, timetabling, and classroom management practices. Most of these school cultural views are implicit and common knowledge to both teachers and learners, so are rarely questioned. As mentioned earlier, these factors interplay with the learners' own cultural and social backgrounds, degree of enculturation to schooling, and physical and emotional state on the day.

Implications for teaching. The teacher is conscious of his/her own beliefs linked to the cultural imperatives of his/her area of schooling, and continually reexamines his/her own beliefs about teaching, learning, and expectations of schooling. She/he is also sensitive to the learners' cultural and social backgrounds and responds in a socially sensitive way to their everyday circumstances.

CONCLUSION

In my description of this model, I have tried to achieve several things. I have tried to provide a simple and understandable description of conceptual learning in science classrooms; I have tried to incorporate elements of both cognitive and social constructivism in a complementary way; and I have tried to illustrate how knowledge of the learning processes described can help teachers in both planning and implementing science lessons. In practice, I have found that teachers who identify with the descriptions in the model are far better able to offer specific pedagogical ideas than I can -- what I provide is merely a seed. I also acknowledge that there are elements of cognitive and social constructivism that have been glossed over or omitted in my discussion of the model, which may have arisen because of a deliberate simplification of the model.

What I have described in this paper reflects my own journey of understanding about learning and teaching in science. It incorporates many contemporary views about cognitive change and constructivism, but most importantly, it provides indications for specific teaching actions which may enhance students' learning in science lessons.

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ACKNOWLEDGEMENT

This paper has been adapted from a presentation at the Australasian Science Education Research Association annual conference, Canberra, Australia, July 1996, and from Chapter 4 of the author's 1997 book *Teaching Science: Exploring the Issues,* published by Central Queensland University Press.

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