TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 4, Sayı 1, Mayıs 2007

Journal of
TURKISH SCIENCE EDUCATION
Volume 4, Issue 1, May 2007

http://www.tused.org

Effective Teaching in Science: A Review of Literature

Atilla ÇİMER*

* Doctorate Student, School of Education, University of Nottingham, Nottingham, United Kingdom

Received: 06.11.2004 **Revised:** 11.05.2006 **Accepted:** 30.07.2006

The original language of article is English (v.4, n.1, May 2007, pp.20-44)

ABSTRACT

This paper presents a review of literature on effective teaching in science. It tries to explore what constitutes effective teaching in science. According to the literature reviewed, six main principles of effective teaching could be identified. The first is *dealing with students' existing ideas and conceptions*. This is important for teachers to help students construct their own understanding and knowledge. This requires teachers to help students activate their existing ideas and conceptions, be aware of them and in the light of scientifically accepted knowledge, modify, change or develop them further. For this purpose, such teaching methods and activities as question-and-answer, discussions either small group or whole class, small group activities, practical work, and using ICT facilities can be employed. The second principle is *encouraging students to apply new concepts or skills into different contexts*. In order to do this, teachers can use practical work, field trips, simulations, writing activities and role-play. The third principle identified is *encouraging student participation in lessons*. Involvement may be through a wide range of teaching and learning activities such as inquiry-based teaching, co-operative learning groups, questioning, discussions, field trips, role playing and so on. *Encouraging student inquiry*; *encouraging co-operative learning among students*; and *offering continuous assessment and providing feedback* are other principles identified from the literature. The paper discusses how these principles contribute to effective science teaching in science in detail. Finally, the importance of presenting research findings for reform attempts to improve the quality of teaching and learning in Turkish schools is discussed.

Keywords: *Effective Teaching, Effective Learning, Science Teaching, Constructivism, Formative Assessment*

INTRODUCTION

This paper presents a review of literature on effective teaching in science. It tries to explore what constitutes effective teaching in science. In doing this, I have also scrutinized such common teaching models as *'the learning cycle'* (Renner, Abraham and Birnie, 1985; Lawson, 1988), '*co-operative learning*' (Kagan, 1992; Johnson, Johnson and Holubec, 1998), *'the 5E instructional model'* (Trowbridge, Bybee and Powell, 2000), *'the conceptual change model'* (Strike and Posner, 1985; Hewson and Hewson, 1988), *'the inquiry model'* (Deboer, 2002), '*the generative learning model*' (Osborne and Wittrock, 1983; Wittrock, 1994) and *'information-processing teaching models'* (Joyce, Weil and Calhoun, 2000a). Based on the theoretical principles of constructivism and the review of these teaching models, I have summarised some of the main principles of effective teaching in science as follows:

1. dealing with students' existing ideas and conceptions,
2. encouraging students to apply new concepts or skills into different contexts,
3. encouraging student participation in lessons,
4. encouraging student inquiry,
5. encouraging co-operative learning among students, and
6. offering continuous assessment and providing corrective feedback,

I discuss these principles in terms of their contribution to effective teaching, and thereby, to student learning in science, especially in biology. In constituting the principles of effective teaching, I will stay focused mainly on constructivist ideas in teaching and learning. The main reason for this is that, in recent years, a major impetus for restructuring science education in many aspects (aims, content, teaching and assessment) has come from the notion of 'constructivism' (Tobin, 1993; Fensham *et al,* 1994; Tobin, Tippins, and Gallard*,* 1994; Driver and Scott, 1996; Treagust, Duit and Fraser, 1996; Alsop, Gould, and Watts*,* 2002; Tytler, Waldrip and Griffiths, 2004).

1. Dealing with Students' Existing Ideas and Conceptions

In this section, I discuss the role of students' existing ideas and conceptions in terms of learning and teaching science and then, describe how to identify these ideas and conceptions. Finally, I present ways to change these ideas and conceptions in order to help students learn science meaningfully.

1.1. Importance of Determining Students' Existing Ideas and Conceptions

Determining students' existing ideas and conceptions has been recognised as an important variable in science teaching and a necessary part of teaching strategies developed (Ausubel, 1968; Driver, 1983; Osborne and Wittrock, 1983; Novak and Gowin, 1984; Scott, Asoko and Driver, 1992; Carr *et al*, 1994; Duit and Treagust, 1998; Littledyke, 1998; Goodrum, Hackling and Rennie, 2002; Tytler, 2002a, 2002b). Hipkins *et al (*2002) argue that teaching science is effective when students' existing ideas, values and beliefs, which they bring to a lesson, are elicited, addressed and linked to their classroom experiences at the beginning of a teaching programme.

The effect of the students' pre-concieved ideas on the quality of subsequent learning is well documented. There is a common belief that students do not arrive in the classroom as empty vessels into which new ideas can be poured by teachers (Carr *et al*, 1994; Leach and Scott, 1995; Vosniadou, 1997; Tytler, 2002a). They can have prior ideas and conceptions about the events and phenomena in the world around them, which might well be different from those intended by the teacher and scientific community. Meaningful learning occurs as students consciously and explicitly link their new knowledge to existing knowledge structure (Ausubel, 1968; Wittrock, 1994; Mintzes, Wandersee and Novak, 1998). This implies that effective instructional approaches have to be based on what is already known by the learner. Therefore, the diagnosis of learners' pre-existing knowledge is important for teachers in order to plan subsequent teaching activities and help students link the new material to what they already know.

Determining students' existing ideas and conceptions in science may increase students' awareness of them, which is necessary for meaningful learning (Ausubel, 1968;

Mintzes, Wandersee, and Novak*,* 1998; Järväla and Niemivitra, 1999; Goodrum, Hackling, and Rennie, 2002). According to Vosniadou (1997) *'[students] do not appear to know that their explanations of physical phenomena are hypotheses that can be subjected to experimentation and falsification. Their explanations remain implicit and tacit.'* (p39). When students become aware of their previously 'tacit' ideas, they have a chance to compare them with scientific ones and change if necessary.

In addition, determining students' pre-existing ideas and conceptions also helps teachers confront any alternative ideas or misconceptions students may have at an early stage in the learning process so that these do not hinder students' learning (Littledyke, 1998). Through determining students' existing conceptions, teachers can develop appropriate instructional strategies that move these unscientific ideas and conceptions towards scientific ones (Järväla and Niemivitra, 1999; Hipkins *et al,* 2002). However, it is noteworthy that there is research evidence that students' alternative conceptions are difficult to shift, and can offer a serious barrier to effective teaching (Glynn and Duit, 1995; Tytler, 2002a). I will discuss this issue later in this section in more detail.

Finally, Hipkins *et al (*2002) indicate that when teachers take into account and build on students' existing ideas, experiences, and values, science education can become more inclusive for students from diverse cultures, girls and boys, students with special needs and special abilities.

In short, these all suggest that there is a need for teachers to determine what ideas and conceptions students have at the beginning of teaching-learning process. Next, I will discuss some of the ways reported in the literature to do this.

1.2. Ways to Determine Students' Existing Ideas and Conceptions

In order to determine students' existing ideas and conceptions, the literature reports a wide range of instructional methods and activities that teachers can use, such as reviewing previous work and stating goals, question-and-answer, group discussions, brainstorming and debating ideas, providing examples, and conducting experiments (Hewson and Hewson, 1988; Abrams, 1998; Littledyke, 1998). In addition, students also need positive supportive learning environments where they feel comfortable and confident enough to disclose their existing ideas and thoughts (Bell and Cowie, 2001).

Teaching methods such as presenting information to students directly from textbooks, providing demonstrations and activities without helping students to focus on the patterns that are similar in the activities, or providing a discovery-oriented lesson without specifically relating it to prior knowledge, on the other hand, may not be successful in helping students to reveal their existing ideas (Smith and Anderson, 1984; Driver, Leach, Millar, and Scott, 1996).

Briefly reviewing previous work at the start of a lesson by explicitly stating the goals of the current lesson activates students' existing ideas and conceptions regarding the new topic and helps retrieve previous learning (Rosenshine and Stevens, 1986; Calderon, Gabbin, and Green, 1996). This helps students to be prepared for understanding the new material. The question-and-answer method is one of the most common methods used by teachers for this purpose (Garnett and Tobin, 1988; Yip, 1998; Amos, 2002). Questions, especially open-ended ones, can stimulate students to expose their informal and perhaps distorted preconceptions developed through their everyday experiences to facilitate their recalling ideas from their long-term memory. Sunal and Sunal (2002) emphasise that the important point here is to help students retrieve as many related experiences, ideas or skills from their long-term memory as possible.

However, since many give up their own ideas reluctantly, finding that their existing 'non-scientific' views work for them in dealing with scientific phenomena in their everyday life (Solomon, 1993), retrieval from long-term memory alone is not enough for meaningful learning to occur. Students also need to change their own understandings of science into ones consistent with the scientific view (Hewson and Hewson, 1983; Strike and Posner, 1985; Duit and Treagust, 1998; Alsop *et al*, 2002).

1.3. Helping Students Change Their Existing Ideas and Conceptions

Students do not change their ideas or conceptions easily but they change them only if they see that the more scientifically valid ideas make sense to them and are more fruitful than their own in explaining a phenomenon and making predictions (Posner, Strike, Hewson and Gertzog, 1982; Hewson and Hewson, 1988; Carr *et al*, 1994; Lee and Brophy, 1996). Therefore, in order for change to occur, students must become dissatisfied with their existing knowledge and be aware of that there may be inconsistencies in their way of viewing the world (Nussbaum and Novick, 1982; Posner, Strike, Hewson, and Gertzog, 1982; Driver *et al,* 1996). This requires a direct contrast between their existing ideas and intended scientific views (Wittrock, 1994). They need to test and develop their models and thought processes in familiar contexts, which they believe are real, representative of everyday experience and under their control. Once they can see that current ideas or conceptions are no longer relevant to solve problems then new learning occurs.

Various strategies are suggested for teachers to use to challenge students' existing ideas. For example, peer interactions can be a valuable strategy (Posner *et al*, 1982; Littledyke, 1998) by creating productive discussions. In such instances, students experience dissatisfaction with their existing concepts, develop plausible new concepts and see the relevance of new knowledge in different contexts (Abrams, 1998).

Furthermore, conducting investigations or inquiry can also strongly challenge students' existing ideas. They can apply their own ideas, observe the process, make predictions about the results and record the results of the experiment. When they achieve unexpected results or find that others disagree with their interpretations or see that their current ideas will not solve the new problem, their existing conceptions are challenged (Goodrum *et al,* 2002). As a result, they come to the understanding that they should either modify or discard these old ideas and construct new ones (Osbourne and Freyberg, 1985; Driver *et al*, 1996).

Similarly, simulations in combination with practical work can be effective in helping students change their non-scientific conceptions (Harlen, 1999; Peat and Fernandez, 2000). For example, viewing the animations as a class facilitates discussion and may bring to light students' misconceptions, which can then be dealt with at class level.

After determining students' existing ideas and conceptions and making students aware of them, teachers need to introduce scientific concepts to help them construct new knowledge. For this purpose, teachers can use short lectures or presentations, watch video or film, read passages from the textbook or reference books (Evans and Boy, 1996; Trowbridge*,* Bybee, and. Powell, 2000; Glenn, 2001). In addition, Rosenshine (1997) suggests that this explanation phase should be clear and short, and allow time for students to process new information and restructure their understanding.

As learners' working memory, where they process information, is small, it takes at least five seconds to organise a 'chunk' of new information and to transfer it to long-term memory. Since the flow of the material during a class is typically much faster, the student's short-term memory is quickly overloaded and learning stops until a space is available in the short-term memory. As a result, students cannot always process the new information rapidly enough because they might lose attention and thus, start daydreaming or not paying attention in the lessons (Anderson, 1998; Bligh, 1998). This is evidenced by research that indicates students retain 70 percent of the information during the first ten minutes of a lecture, but only 20 percent of the last 10 minutes (McKeachie, 1994). Bligh (1998) suggests that the limit to students' effective attention is 25-30 minutes. All these, therefore, suggest that teachers should give short breaks or provide examples for students to process new information in their working memory (Svinicki, 1999). When there is no new information coming, students can digest what is being said more readily.

However, teachers should not rely on lectures too much for introducing new knowledge and skills because, as a traditional teaching method, lecturing can make students passive in the lessons, leaving too little time for them to process the new information (Parkinson, 2004). In addition, particularly in biology, it can lead to a view of biology as a 'fact mountain' (Griffiths and Moon, 2000). A strictly lecture-based presentation of facts and concepts may lead students to believe that everything has been figured out already and in order to pass their examination they must memorise facts and concepts instead of trying to understand them.

In explaining new concepts or ideas, there are two important conditions that teachers should consider: creating attention in students and providing examples and opportunities for students to practise their ideas.

1.3.1. Creating Attention in Students

Focusing student attention on the material to be learned is an important factor in effective learning (Bligh, 1998; Joyce *et al,* 2000b). There is a school of thought which proposes that teaching materials should match individual learning styles, i.e. visual, auditory and kinaesthetic (Rosenshine, 1997; Nelson, 1999; Joyce *et al*, 2000a, 2000b; Nayar and Pushpam, 2000). Moreover, students remember best those ideas or concepts that are presented in a way to relate their sensory channels, e.g. audio and visual representations, pictures, charts, models and multimedia (Cyrs, 1997; Nayar and Pushpam, 2000).

The use of visual teaching aids can provide more concrete meaning to words, show connections and relationships among ideas explicitly, provide a useful channel of communication and strong verbal messages and memorable images in students' minds, and make lesson materials more interesting to students. (Duit, 1991; Cyrs, 1997; Harlen, 1999; Joyce *et al*, 2000a). For example, models help students make sense of the world by finding out the why of things and make abstract or imagined concepts seem more real to students (Raghaven and Glaser, 1995; van Driel and Verloop, 1999).

Furthermore, multimedia can help teachers bring the real world to students through the use of sound and video, interacting with a picture or diagram by enlarging or rotating it (Harlen, 1999; Boohan, 2002). Nayar and Pushpam (2000) report that when teachers use appropriate media integrated in the curriculum, their students achieve significantly higher learning outcomes. Similarly, Wisniewski (1994, quoting Killermann, 1998 p7) found that students who watched films about AIDS performed significantly better than those students who did not on a test conducted a week later. Wisniewski (1994) concluded that this might be because of the fact that showing films might help in some way to activate their long-term memory of the subject and the content of the lessons at later time.

To summarise, when visual materials accompany verbal explanation, students may pay more attention to the material to be learned, conceptualise and comprehend abstract and difficult ideas, thoughts, and data better in their mind, and store and remember more information efficiently.

1.3.2. Providing Examples and Opportunities for Students to Practise

In order for students to comprehend new ideas or concepts and construct their own knowledge, they need to see clear examples of what the new ideas or skills represent (Rosenshine, 1997; Trowbridge *et al*, 2000). Furthermore, in learning new materials or skills, students should be given extensive opportunity to manipulate the environment (Joyce *et al,* 2000a) as, according to Piaget (1978), students' cognitive structures will grow only when they initiate their own learning experiences. For example, Rosenshine (1997) suggests that teachers should provide tasks where students can engage in cognitive processing activities of organising, reviewing, rehearsing, summarising, comparing, and contrasting with other students, or with the teacher or working alone. In addition, teachers should encourage informal discussions and structure science activities so that students are required to explain and justify their understanding, argue from the data, justify their conclusions and critically assess the scientific explanations of a matter (Abrams, 1998).

Teachers can demonstrate skills and work on a problem on the board whilst discussing the problem. This demonstrating or modelling skills is necessary because when an idea or skill is modelled for students in different ways, it will be more meaningful to them (Potari and Spiliotopoulou, 1996).

Teachers can also use graphic organisers (Wittrock, 1994; Cyrs, 1997; Mintzes *et al,* 1998; Trowbridge and Wandersee, 1998) as such devices help students to integrate new information into their existing knowledge structures. As a result, such organisation can facilitate retrieval, help students see the relationships among ideas and how they are connected, speed up comprehension, and improve note-taking (Novak and Gowin, 1984; Cyrs, 1997; Rosenshine, 1997). Graphic organisers can also help students to construct their understanding while reading a text from textbook, watching a film or listening to the teacher (Joyce *et al* 2000a).

In short, according to the literature then, for effective learning to occur, teachers should first identify students' prior ideas, make students aware of them and, in the light of these ideas, help students construct their own understanding. After that teachers should provide opportunities for students to apply their newly acquired knowledge to different situations. The next section will focus on this principle.

2. Encouraging Students to Apply New Concepts or Skills into Different Contexts

Schaefer (1979) argues that if the concepts taught at school are not related to students' everyday lives, they may fail to use them adequately outside the school. Thus, their knowledge may remain in the form of acquired isolated knowledge 'packages'. Effective learning requires students to apply newly acquired concepts or skills to different contexts (Schollum and Osborne, 1985; Wallberg, 1991; Good and Brophy, 1994; Gallagher, 2000; Yip, 2001). As a result, they can achieve higher learning outcomes and use their knowledge or skills to solve the problems in their everyday life. For these reasons, teachers should create opportunities that allow students to apply their knowledge to real life situations. Gallagher (2000, p.313) suggests that teachers should:

> *"..identify practical applications of concepts, use practical experiences and applications to make connections between concepts and 'real world' experiences in ways that enrich understanding of concepts, and show how knowledge of one set of concepts forms the foundation for learning about other concepts."*

Teachers can employ various methods to help students to apply their knowledge, such as conducting practical work, field trips, simulations, writing activities and role-play. Following is a brief discussion of some of these methods drawn from the literature.

2.1. Practical Work

Practical work can provide a good opportunity for students to apply their newly acquired knowledge or skills and gain first-hand experience of phenomena talked about in theory (Kirschner, 1992; Hodson, 1993; 1996; Arce and Betancourt, 1997; Johnstone, 1997; Amos and Boohan, 2002; Millar, 2002). When students engage in practical work, they can test, rethink and reconstruct their ideas and thoughts. For these reasons, many studies reported that practical work improved students' learning and understanding (Hewson and Hewson, 1983; Stohr-Hunt, 1996; Dawe, 2003). Dawe (2003) argues that such positive outcomes may be as a result of students' gaining ownership over the concepts they learn as they 'discover' the knowledge themselves during practical work.

In relation to practical work, simulations can be used to replace laboratory work when laboratory work cannot be done in schools (Raghavan and Glaser, 1995; Good and Berger, 1998; Peat and Fernandez, 2000). So, they can help students understand invisible conceptual worlds of science through animation, which can lead to more abstract understanding of scientific concepts (Joyce *et al*, 2000b; Hwang and Esquembre, 2003). Students can understand not only just what happens, but also how and why. Using simulations in science lessons also improves students' higher order skills like application and analysis, and thus, helps them comprehend the topic better (Rivers and Vockell, 1987; Henson and Eller, 1999). For example, Rivers and Vockell (1987) found that using computerised simulations enhanced high school biology students' problem solving skills.

2.2. Field Trips

Field trips can provide students with meaningful contexts where they can connect their knowledge with the natural world and see examples and practical applications of scientific concepts or processes (Glynn and Duit, 1995; Griffiths and Moon, 2000; Tytler, 2002a). For example, Scherf (1992, quoting Killermann 1998 p5) investigated the effectiveness of field trips on students' achievement and attitudes, and found that the students who participated in the lessons outside the classroom, demonstrated significantly greater ability to recognise plants than the students who studied plants only in the classroom.

However, fieldwork is not always possible due to a limited teaching budget and increasingly busy curricula. Yet, teachers can bring the natural world into the classroom by providing live plants, animals, pictures, models and the display of student work (Glynn and Duit, 1995; Griffiths and Moon, 2000). For example, Bauhardt (1990, quoting Killermann 1998 p6) reported that the use of living animals including the earthworm, the darkling beetle and the house spider in biology lessons positively influenced students' attitudes and increased their knowledge about the animals. Bauhardt (1990) pointed out that it was because the students found working with the living insects more motivating which in turn led to effective learning.

Furthermore, virtual field trips were also reported to be used successfully (Peat and Fernandez, 2000). They can help teachers and students recreate field trips electronically and take part in activities not available in the laboratory and visit inaccessible sites of biological interest through computers and the Internet. This suggests that through internet, in the future students will be able to have more opportunities to 'visit' or see the sites, biological processes and events in their original places without actually leaving their classrooms. I believe that such a learning opportunity will make biology learning much easier and more interesting for students.

2.3. Writing Activities

Writing their own explanations, summaries, or reports can allow students to apply newly acquired concepts or ideas to different contexts. While writing individually or with others, students can think critically and negotiate their understanding, both within the social setting and against the current knowledge of the scientific community (Rillero, Cleland, and Zambo, 1996; Keys, 1999; Keys, Hand, Prain and Collins, 1999). As a result, they can build explanations and make sense of information from sources such as class discussions, laboratories or textbooks.

However, conventional writing activities, like copying notes from textbooks or taking down a teacher's dictation may not be helpful for students to understand science and communicate with others (Brown, 1994; Henderson and Wellington, 1998; Keys *et al*, 1999). In addition, these activities make students passive and lessons boring because they do not really engage students' brains (Henderson and Wellington, 1998). Therefore, Henderson and Wellington (1998, p39) suggest that teachers should explore *'different ways of getting students to present written records of their investigations and observations and to give them the opportunity of showing that they understand a scientific topic or concept'.* For this reason, recently, such forms of writing as journals, questions, cartoons, and brief narratives have gained popularity as a means of helping students to understand the scientific material (Prain and Hand, 1998; Hand, Prain, Lawrence, and Yore, 1999).

Overall, so far in this section, I have focused on the importance of students' applying their knowledge and skills to different contexts in an effort to increase their learning and understanding, alongside some of the methods and activities that allow students to do so. In the next section, I will try to explain another effective teaching principle, which is to encourage student participation in lessons.

3. Encouraging Student Participation in Lessons

Recently, there has been much emphasis on participatory classroom activities because there is a general agreement that effective learning requires students to be active in the learning process (Roth and Roychoudhury, 1994; Strage and Bol, 1996; Stepanek, 2000; Parkinson, 2004). In addition, researchers believe that the more students are involved in the learning process, the more they learn the topic (Trowbridge *et al*, 2000; Deboer, 2002). Taras (2002) suggests that student-centred learning has, in theory, promoted and brought about greater student participation and involvement. Therefore, for students to be at the centre of the learning and teaching process, their needs and requirements must be at the heart of this process.

Meaning can only be formed in students' minds by their own active efforts (Saunders, 1992) and cannot be created by someone else for students. This suggests that students are not simply passive recipients of information from the teacher, computer, textbook or any source of information during the learning process. They have to wrestle with an idea in their own minds until it becomes meaningful to them.

Joyce *et al* (2000a) state that the opportunity to exchange views and share personal experiences produces the 'cognitive conflict' that is fundamental to intellectual development. In order to foster cognitive conflict, students need opportunities to pose questions about science, to work with others, to conduct investigations, present and defend their ideas, solutions, and findings, and assess their own and other students' reasoning (Pope and Gilbert, 1983; Tobin and Gallagher, 1987). These all imply that they need to participate in learning process.

Active learning techniques can empower students to make good decisions and take an active role in their own learning, increase their motivation to learn, foster and value the diverse voices of students and reduce disciplinary problems (McCombs and Whisler, 1997; Stepanek, 2000; Deboer, 2002). Researchers believe that this is a result of a sense of ownership and personal involvement that active learning creates. In active learning contexts, students see their work as important because they feel important and their ideas and findings are valued.

Amos (2002) argues that students' active participation also requires a positive, supportive learning environment in which they feel free to ask their own questions, express their ideas and thoughts and receive support and encouragement. When students realise that their ideas and thoughts are valued and treated with respect by the group members, when they actively involve themselves in group activities, they feel more confidence, and thus, participate more in the activities (Brown, 1995).

Many different methods and strategies have been suggested for involving students in lessons and engaging them in active learning (Trowbridge et al 2000; Deboer, 2002; Goodrum et al, 2002). However, in order for any method to be successful, effective lesson planning is essential (Henson and Eller, 1999; Harlen, 1999). A lesson plan requires teacher to be clear about the sequence of the activities in the lessons, the purpose and goals of the lessons. The planning process involves clarification of the roles of the teacher and students. Thus, it makes easier for students to follow the teacher's material and encourages them to participate more in the lesson and take responsibility for their own learning (Good and Brophy, 1994; Calderon et al, 1996). For these reasons, effective lesson planning has a positive effect on students' learning (Brown, 1994; Tomic, 1994; Glenn, 2001). Moreover, according to the above, teachers should allow some flexibility in lesson planning in order to encourage students to participate more in the lessons. It is important to be sensitive to the mood of the class and if something is not going well to abandon it and move on or change tack completely. Otherwise, a rigid lesson plan potentially hinders rather than helps the teaching-learning process, since it could prevent students from being involved in the lessons and reduce their creativity.

Questioning is the most common strategy that teachers use for involving students in the learning process (Bliss, 1995; Glenn, 2001; Amos, 2002). Indeed, Amos (2002) reports that up to one-fifth of what a teacher says in a classroom is likely to be in the form of questions. If teachers ask open-ended questions, they allow students to think freely and flexibly, to express their own ideas and thoughts without thinking that they have to give one 'right' answer and they promote successful discussions that stimulate student participation (Harlen, 1999).

Amos (2002) supports the use of open-ended questions, arguing that closed and subject-oriented questions that rely on linear processes and logical reasoning discourage students from thinking differently from the teacher and may deter students from answering the questions asked.

In addition to the nature of the questions asked, the process of asking questions is also important for students' learning and development. Providing sufficient 'wait time', about 3-5 seconds, after asking a question for students not only increases student participation but also provides them with opportunity to think critically and create more ideas and responses (Yates and Yates, 1990; Bliss, 1995; Trowbridge *et al,* 2000; Amos, 2002).

Role-playing can also be a useful teaching and learning activity to encourage students to participate more in the lessons and facilitate their understanding. However, researchers report that role-playing in science lessons is underrated and underused, often because of misconceptions about what role-play is and how it can be put to use in science education (Resnick and Wilensky, 1998; McSharry and Jones, 2000). McSharry and Jones (2000) point out that the theory behind the use of role-play in science teaching and learning supports 'active', 'experiential' or 'student-centred' learning. Therefore, students are encouraged to be physically and intellectually involved in their lessons to allow them to both express themselves in a scientific context and develop an understanding of difficult concepts. Resnick and Wilensky (1998) also point out that role-playing activities play a significant role in helping students to learn complex topics.

Furthermore, McSharry and Jones (2000) argue that merely explaining to students about their environment may not be the best method for helping them to gain an understanding of why it is there or how the processes at work in the environment have formed it. However, role-plays, such as those describing predator–prey relationships or antibody–antigen interactions, can give students a chance to experience these events in a physical way, which may be more appropriate to their personal learning style. As a result, students can understand abstract and difficult topics that are not always visible phenomena. Indeed, Fadali, Robinson, and McNichols (1999) point out that role-playing may be useful in secondary science classes as a way of introducing and familiarising students with difficult, abstract or complex concepts in biology and the physical sciences. Finally, Maier (1989) argues that teachers, trainers or supervisors favour role-play as a handy means of enlivening the learning content; in particular, this model brings forth detailed and concrete study materials which are more difficult to pinpoint by the way of lecture and discussion.

Another useful method for enabling students to participate in the learning process is to conduct practical work (Hodson, 1993; Amos and Boohan, 2002; Millar, 2002). The important point in doing practical work is to ensure that students are mentally active because engaging students in practical tasks does not mean that they are active in their learning.

Inquiry-based teaching and learning (Trowbridge *et al*, 2000; Deboer, 2002) and co-operative learning groups (Slavin, 1990; Kagan, 1992; Jones and Carter, 1998; Goodrum *et al,* 2001) are also useful contexts where students actively participate in learning process to develop their own understandings of scientific knowledge. I will discuss these in the subsequent sections in more detail.

In short, student participation is necessary for their learning. Active participation can increase students' learning, understanding and motivation to learn. Teachers should make sure that students are mentally active in the lessons and create opportunities for them to participate in the lessons.

4. Encouraging Student Inquiry

In recent years, there has been a growing movement to integrate inquiry into science education (Tamir, 1983; Trowbridge *et al*, 2000; King, Shumow, and Lietz, 2001; Deboer, 2002). The importance of inquiry grew from Dewey's ideas. Dewey (1938) argues that citizens in a democratic society should be inquirers with regard to the nature of their physical and social environments and be active participants in the construction of society. They should ask questions and have the resources to find answers to these questions, independent of external authority. Since there is a shared, collaborative aspect to life in a democratic society, students also need to develop a capacity for communal inquiry into the nature of the world. Therefore, formal education needs to give students the skills and dispositions to formulate questions that are personally significant and meaningful to them.

Trowbridge *et al* (2000, p207) define inquiry as '*the process of defining and investigating problems, formulating hypotheses, designing experiments, gathering data and drawing conclusions about problems'*. A potential result in inquiry-based teaching enables students to gain insights into the nature of scientific inquiry (Amos and Boohan,

2002) and understand how and why to apply the scientific method at the same time as they come to understand the subject. They can also understand what science is like and what scientists do (Harlen, 1999).

Engaging in inquiry can also help students develop a wide range of skills, such as psychomotor and academic or intellectual skills. Psychomotor skills involve doing something physical, like gathering and setting up apparatus, making observations and measurements, recording data and drawing graphs while academic or intellectual skills include analysing data, making comparisons, evaluating results, preparing reports and communicating results to the others or the teachers. Furthermore, students' attitudes and dispositions such as curiosity, inquisitiveness, and independence of mind, freedom from external authority, and a personal search for meaning about the world can also improve. Therefore, it would appear that inquiry-based learning can prepare students to be lifetime learners rather than classroom-only learners (Tamir, 1983; Trowbridge *et al,* 2000; King *et al*, 2001; DeBoer, 2002).

In order to implement inquiry-based teaching successfully in science, teachers should fulfil some important conditions (Suchman, 1966 quoting Trowbridge *et al* 2000 p210). First of all, teachers should allow students to have 'freedom' to seek out desired information. Students must be allowed to try out their ideas and invent ways of accounting for what they see and can ask their own questions (Tamir, 1983; Dillon, 1990; Lemke, 1990; Bliss, 1995; Dori and Herscovitz, 1999; Joyce *et al*, 2000a; Trowbridge *et al,* 2000; Amos, 2002). Furthermore, teachers should encourage students to discuss and talk to one another about the topic being taught during the class (Lemke, 1990; Trowbridge *et al*, 2000). Hipkins *et al (*2002) argue that in any format, discussion can provide opportunities for students to clarify and share their own understandings, test out their understandings, ask questions and challenge the views of other students and the teacher, and use the new ideas with confidence. Moreover, Trowbridge *et al* (2000) suggest that teachers' asking and 'telling' should be at a minimum level because classrooms where the teacher is always the questioner and students are the respondents, do not easily promote student inquiry and participation. Instead, they encourage student passivity and dependence. Therefore, teachers need to use less question-answer dialogue but organise more class time for student questions, student individual and group reports and whole class and small group discussions.

However, there are issues in this approach which need to be addressed: classroom management, time, teacher doubts about students' ability to originate a feasible research project and distrust that students will follow through to the end of the investigation (Abrams, 1998). In addition, teachers' subject matter knowledge may also prevent students from asking their own questions (Wragg, Bennett and Carre, 1989; Glenn, 2001; Alsop *et al*, 2002; Amos, 2002). Teachers who have low levels of understanding of subject matter knowledge may not wish their students to ask questions because they may not know how to respond. Therefore, as Lemke (1990) argues, it would become difficult for these teachers to move away from a position of student control through questions.

The second condition for implementing inquiry-based teaching is that teachers should provide a 'responsive environment', which can be a classroom, a laboratory or the outdoors on a field trip (Suchman, 1966). It is not enough to supply only a sterile classroom or lecture hall for students. Instead students need a range of resources including books, a laboratory with enough equipment, library, and computers (Joyce *et al*, 2000a; Trowbridge *et al,* 2000). For example, using ICT facilities makes student inquiry easier, quicker and a richer process than doing the equivalent using a textbook (Boohan, 2002). Mintzes *et al* (1998) argue that as long as they are carefully guided in their search of knowledge, students can obtain important gains from the Internet in their inquiry process.

Through using the Internet, students can explore information in a variety of ways and access the updated scientific information about a particular topic that has not been covered in textbooks (Mistler-Jackson and Songer, 2000; Peat and Fernandez, 2000; Boohan, 2002). This can enable students to ask their own questions to professional scientists and to use the same or slightly modified data and tools used by professional scientists around the world.

The third condition suggested by Suchman (1966) is that teachers should provide 'focus', which means that inquiry is a purposeful activity, a search for particular meaning in some event, object or condition that raises questions in the inquirer's mind. It is stimulated by confrontation with a problem. Knowledge is generated from inquiry (Joyce *et al,* 2000b).

The final condition that teachers should fulfil is to provide 'low pressure'. This indicates that students will gain their reinforcements directly from the success of their own ideas in adding meaning to the environment (Suchman, 1966). In order to provide 'low pressure' to students, teachers should be positive and flexible to encourage students further (Joyce *et al,* 2000b).

Furthermore, there is also need for a positive and supportive learning environment in order to foster student inquiry and to encourage students to ask their own questions (Alsop *et al,* 2002; Amos, 2002; McKeon, 2002). In non-threatening and trusting classroom environments, students can show their willingness to seek understanding and express their curiosity. On the contrary, in such classrooms where the conditions are not supportive and encouraging, students may not put forward questions.

The teachers' role in encouraging student inquiry is often dependent on the creation of a co-operative social environment, where students learn how best to negotiate and solve conflicts necessary for problem solving (Joyce *et al*, 2000a). In addition, teachers should also '*guide students in methods of data collection and analysis, help them frame testable hypotheses, and decide what would constitute a reasonable test of a hypothesis'* (p98). They should ask open-ended, higher level questions to their students to encourage them to find out answers to the problems at hand and reveal their own ideas and thoughts (Dori and Herscovitz, 1999; Glenn, 2001; Amos, 2002).

To summarise, inquiry-based teaching is helpful for students to construct their own meaning and understanding and to gain some important skills that they can use throughout their lives. Therefore, teachers should encourage inquiry-based learning among students and create opportunities for them to conduct inquiry about a particular problem or issue.

5. Encouraging Co-Operative Learning Among Students

Recently, encouraging students to work or co-operate with each other in constructing their own understanding has been a highly valued principle of effective teaching in science (Slavin, 1990; Kagan, 1992; Munro, 1999). The popularity of co-operative learning rose rapidly during the early 1980s as the use of individualistic 'mastery learning' declined (Jones and Carter, 1998). Educators realised that the motivational and mediating impact of peer-peer interactions was the missing part of the individualised mastery instruction. Therefore, educators viewed co-operative learning to be a more efficient way of meeting the range of needs of students in a science classroom.

Theoretical foundations of co-operative learning have been strongly affected by Vygotsky's ideas about learning. Vygotsky (1978) indicates that learners do not construct knowledge in isolation but through social interaction with their peers and thus, the interactions among learners affect each other's learning. This implies that working with other students is a critical component of the process of knowledge construction. Therefore, social constructivist views imply a social context where ideas and conceptions are communicated, shared, tested, negotiated, and reported by students and the teacher (Vygotsky, 1978; Tobin *et al,* 1990; Driver, Asoko, Leach, Mortimore, and Scott, 1994). Consequently, the prevailing view of learning in science has been a social constructivist perspective (Solomon, 1993; Yager, 1995; Jones and Carter, 1998; Tytler, 2002a).

Social constructivist views put a great emphasis on language and communication. This suggests that students need to talk with their peers and teacher in order to articulate their prior ideas about a concept and their explorations made in an investigation, to clarify their thinking and to correct their misconceptions (Driver *et al,* 1994; Watts, 1994; Osborne, 1997). Classroom-based research suggests that students can meet these aims in co-operative learning groups (Jones and Carter, 1998).

Co-operative learning groups promote community aspects of the classroom and the role of discussion with peers in helping students to learn science. This offers many benefits for students for their learning and growth. For example, peer-peer discussions in co-operative learning groups can promote meaningful learning by helping learners to help each other to incorporate new experiences and information into their existing cognitive structures in a non-arbitrary and non-verbatim way (Ausubel, 1968; Novak and Gowin, 1984; Mintzes and Wandersee, 1998). Therefore, it is believed that co-operative learning can foster the development of deep understanding (Spitulnik, Zembal-Saul and Krajcik, 1998; Joyce *et al*, 2000a).

In co-operative learning groups, peers can moderate each other's learning in ways that are distinctively different from the teacher's methods (Jones and Carter, 1998). As students are at similar developmental levels (Piaget, 1960; Vygotsky, 1978), they can sometimes be more effective than adults in helping individuals to construct meaning. In other words, since they generally use similar words and terms while speaking, peers can understand each other's talk and explanations more easily. For example, a peer may help a confused student by rewording the teacher's explanation.

Co-operative learning groups are useful contexts for promoting productive discussions among students (Kagan, 1992; Osborne, 1997; Johnson *et al,* 1998), providing an environment free of some of the social pressures of teaching science with the teacher (Abrams, 1998). Students may have the opportunity to reveal their existing ideas and clarify them, ask questions and challenge each other's ideas and provide rich interactions for creating connections among concepts (Spitulnik *et al,* 1998). Such discussions may create a pool of students' ideas and productive arguments over disagreements. As a result, the exchange of ideas in small groups may promote the development of complex conceptions (Millar and Driver, 1987). In addition, they can provide cognitive conflict that can promote reconstruction of another person' knowledge (Abrams, 1998; Jones and Carter, 1998).

Furthermore, effective co-operative learning groups can provide an opportunity for students to give and receive feedback from other students regarding their understanding (Brown, 1994; Joyce *et al*, 2000a, 2000b). Consequently, students can learn from each other and develop a shared understanding of the topics they are learning. Sharing diverse experiences enriches a group's problem solving and creativity skills (Jones and Carter, 1998). Moreover, seeing that others' views can enrich and help their thinking can encourage students to tolerate and accept alternative points of view as well (Abrams, 1998).

In addition, group members benefit from each other's existing competencies and skills (Jones and Carter, 1998). For example, a student who already knows how to handle a microscope, a balance or other science laboratory tools can help other members' knowledge construction and skill development.

Overall, because of these benefits, numerous studies in very diverse school settings and across a wide range of content areas have reported that co-operative learning can positively increase students' achievement and develop their skills and attitudes towards the subject being studied (Sharan and Shacher, 1988; Slavin, 1990; Kagan, 1992; Stahl, 1994; Osborne, 1997; Johnson *et al*, 1998). For example, Sharan and Shacher (1988) reported that students with poor achievement taught by using a group investigation method throughout a year-long course in social studies achieved average gains nearly two and a half times those of the lower achievement students taught by the whole-class method. In fact they scored more highly than the higher achieving students taught with whole-class method. These can be explained by the fact that the shared responsibility and interaction produce more positive feelings toward tasks and others, generate better inter-group relationships and result in better self-images for students (Joyce *et al,* 2000b).

However, co-operative learning requires teachers to carefully plan tasks and to closely monitor students' access to power and authority within the group, which can vary according to a myriad of factors including gender, race, personality and socio-economic status. Without careful planning and monitoring, despite its wide advantages, co-operative learning can be of little help to the learner (Jones and Carter, 1998), as it can isolate and restrict a group member's access to the materials, ideas and peer assistance.

6. Offering Continuous Assessment and Providing Performance Feedback

Effective teaching requires teachers to check continuously the development of students' understanding and give detailed positive feedback in order to make sure that students correctly integrate new knowledge into the existing knowledge structure (Svinicki, 1999; Cimer 2004). In addition, in order to identify and correct students' mistakes at an early stage before they become too deeply embedded, teachers need to continuously monitor and evaluate students' understanding (Rosenshine and Stevens, 1986; Wallberg, 1991; Littledyke, 1998; Hipkins *et al,* 2002).

The process of evaluating students' work or performance and using the information obtained from these practices to modify teachers' and students' work in order to make teaching and learning more effective is known as formative assessment (Gipps, 1994; Black, 1995; Black and Wiliam, 1998). Research has shown that it has great potential for improving the quality of teaching and learning (Black and Wiliam, 1998). Black and Wiliam show that it is the essential feature in good teaching as well as in efficient learning: *'We focus on one aspect of teaching: formative assessment. But we will show that this feature is at the heart of effective teaching.*' (p140). Furthermore, Black and Wiliam note that a focus by teachers on 'assessment for learning', as opposed to 'assessment of learning', produced a substantial increase in students' achievement. In addition, if assessment occurs early in the teaching-learning sequence, it can reveal information about students, which can be used to guide the planning of teaching so that it takes account of students' existing conceptions. Osborne and Wittrock (1983) argue that the more teachers learn about students' learning the more they realise the powerful influences that existing conceptions have on students' construction of meaning and their learning from classroom activities. Therefore, assessment strategies that reveal students' existing conceptions early in the instructional sequence have been included in a number of constructivist teaching models (Cosgrove and Osborne, 1985; Driver and Oldham, 1986; Littledyke, 1998).

Furthermore, the emphasis of formative assessment on providing students with continuous feedback on their performance aims to engage students in self assessment of their learning, and hence, it can be argued that formative assessment can increase student participation in the learning process (Black, 1993; Black and Wiliam, 1998; Cimer, 2004).

Students engaging in self assessment have more control over their learning and use the feedback to modify their learning behaviours (Goodrum *et al*, 2002).

The effectiveness of formative assessment is strongly related to the quality of the feedback given to students (Crooks, 1988; Black and Wiliam, 1998) and action taken by students based on the feedback (Sadler, 1989). Feedback is an integral part of learning and teaching. Providing detailed and ongoing feedback is necessary for effective learning as students need information about their accomplishments in order to grow and progress (Brookhart, 1997; Hipkins *et al,* 2002). Cross (1996, p4) emphasises the importance of feedback for students by saying: *'One of the basic principles of learning is that learners need feedback. They need to know what they are trying to accomplish, and then they need to know how close they are coming to the goal.*' Cross also provides a vivid and evocative metaphor for learning without feedback where it is likened to learning archery in a darkened room. Feedback helps students find out how well they understand the new material, what they have done correctly and what their errors are (Joyce *et al,* 2000a). Therefore, educators report that effective teachers frequently provide feedback specific to the subject matter being covered and if necessary, take remedial action, such as providing further explanation or repeating the key ideas and concepts (Rosenshine and Stevens, 1986; Wallberg, 1991). Taking such remedial action can improve students' learning (Yates and Yates, 1990; Black and Wiliam, 1998).

The important point in giving feedback to students is to help them discover their own mistakes, rather than simply telling them what they have done wrong or the pieces they are missing (Stepanek, 2000; Tytler, 2002b). Correcting students' mistakes by telling them the right answer does not make for effective strategies. 'Judgements' and 'being wrong' might cause students not to reveal and discuss their ideas in the classroom. Besides, such a practice encourages passive learning and teacher-dependency.

Furthermore, Brookhart (1997) indicates that the feedback should provide students with adequate information about their performances and should guide students about what to do next to improve. For example, simply saying 'excellent', 'not as good as it could be', 'you must do better next time', and 'unsatisfactory' or 'try harder' might not be helpful for students to improve themselves.

In formative assessment, students' questions and ideas might be very helpful for teachers to uncover their knowledge structure and understand their thinking and understanding (McCombs and Whisler, 1997; Dori and Herscovitz, 1999). For example, Watts, Gould and Alsop (1997, p62) state '*… the teacher can appreciate where the pupil is at through the quality of the questions the child asks.'* While asking questions, students shape and expose their thoughts and understanding, which might also reveal their incomprehension and routes through which they are seeking understanding.

The quality of teacher questions is also important. In checking students' understanding, teachers should ask open-ended questions that allow students to express their own understanding and conceptions, and put less emphasis on recalling facts that reduce opportunities for students to be creative and critical in their thinking (Harlen, 1999; Amos, 2002; She and Fisher, 2002). Amos (2002) argues that such questions require students to apply, analyse, synthesise, and evaluate information, which were considered as 'high order thinking skills' in Bloom's Taxonomy of Educational Objectives (Bloom, 1956). In addition, She and Fisher (2002) suggest that questions should help students interpret their observations, link new learning to what students already know, and stimulate their thinking.

Although test-based questions might target students' higher order thinking skills, according to Clements and Ellerton (1995), a correct answer on a multiple choice test may not necessarily indicate that the student has a correct and complete understanding of the underlying concept. For example, the student may have recalled an answer previously worked out, copied without understanding, guessed, meant something different and so on (Rowntree, 1987; Clements and Ellerton, 1995). Such an assessment may not give teachers correct information about students' understanding and thinking and thus, may not help students' progress. Therefore, the essential way to assess how students organise information is to ask them to provide explanations of these processes (Pallrand, 1996). Student explanations can open a window, for teachers, to the students' knowledge structure that tests cannot provide. Indeed, Osborne (1997) argues that it is only when students are required to explain a concept to somebody else that they really start to understand it. Therefore, Pallrand (1996) states that through examining student explanations, teachers can gain insights into many aspects of the ways students seek and analyse information as well as the weak areas in their knowledge structure and misunderstandings.

In short, continuous assessment and providing detailed performance feedback is necessary for students to improve their understanding and learning.

CONCLUSIONS

In this paper, I have presented a review of literature on effective teaching in science. I have also tried to explore what constitutes effective teaching in science. I focused on the following six common principles of effective teaching. These are:

- dealing with students' existing ideas and conceptions,
- encouraging students to apply new concepts or skills into different contexts,
- encouraging student participation in lessons,
- encouraging student inquiry,
- encouraging co-operative learning among students, and
- offering continuous assessment and providing corrective feedback,

Recent literature on effective teaching in science strongly suggests that teachers should determine students' existing ideas or conceptions in order to help them construct their own understanding and knowledge. This requires teachers to help students to activate their existing ideas and conceptions, be aware of them and in the light of scientifically accepted knowledge, modify or change them. Therefore, appropriate teaching for this purpose should include such teaching methods and activities as question-and-answer, discussions either small group or whole class, small group activities, practical work, and using ICT facilities.

Teachers should also encourage students to apply their newly acquired knowledge and skills to different contexts. Research suggests that teachers can use such activities as conducting practical work, field trips, simulations, writing activities and role-play. Furthermore, encouraging students to develop their own summarises, metaphors, analogies, explanations, diagrams, concept maps and pictures can also be useful tools for constructing and applying knowledge.

Effective teaching also puts a great emphasis on student participation in the learning process. Research suggests that students have to be active rather than simply passive recipients of information from the teacher, computer, textbook or any other source of information in the learning process because meaning is constructed in students' minds according to learning contexts. Involvement may be through a wide range of teaching and learning activities such as inquiry-based teaching, co-operative learning groups, questioning, discussions, field trips, role playing and so on.

Effective teaching also emphasises the importance of continuous assessment of students' understanding and providing detailed performance feedback in terms of improving students' understanding and learning.

To summarise, so far I have outlined effective teaching from the perspective of the literature in both general and science education. Given the current Turkish context, it is important to present an international perspective on effective science teaching to move developments forward. Therefore, the detailed presentation of research findings serves as a basis for reconceptualising teaching praxis in Turkey and is used as a catalyst for reform. I am convinced that discussing these principles in teacher education courses at both pre-service and in-service levels will contribute to the development of student and existing teachers' repertoires of teaching and learning methods and strategies and in turn increase the quality of teaching and learning in schools. However, I also believe that in order to make teacher education courses more effective and provide better quality courses, there is also need to understand the current views of effective teaching in Turkey. For example, knowing effective teaching from both teachers' and students' perspectives will give opportunities for student teachers to construct their own knowledge and understanding of effective teaching and develop their own theories of teaching and learning. Also, by studying current views of effective teaching of teachers and students in Turkey, teacher educators can better understand ways to improve the Methods Courses in teacher education programs.

REFERENCES

Abrams, E. (1998). Talking And Doing Science: Important Elements In A Teaching For Understanding Approach, in J.J., Mintzes, J.H. Wandersee, and J.D. Novak, (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 308-322.

Alsop, S.J., Gould, G. and Watts, D.M. (2002). The Role Of Pupils' Questions In Learning Science, in S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science: Perspectives on Practice, RoutledgeFalmer*, London, pp 39-48.

Amos, S. (2002). Teachers' Questions In The Science Classroom, in S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science, RoutledgeFalmer*, London, pp 5-15.

Amos, S. and Boohan, R. (eds). (2002). *Aspects of Teaching Secondary Science, RoutledgeFalmer*, London.

Anderson, R.S. (1998). Why Talk About Different Ways To Grade? The Shift From Traditional Assessment To Alternative Assessment, *New Directions for Teaching and Learning,* 74: 5-16.

Arce, J. and Betancourt, R. (1997). Student Designed Experiments In Scientific Lab Instruction, *Journal of College Science Teaching*, 27 (2).: 114 - 118.

Ausubel, D.P. (1968). *Educational Psychology: A Cognitive View,* New York; Holt, Reinhart and Winston.

Bell, B. and Cowie, B. (2001). *Formative Assessment and Science Education,* The Netherlands: Kluwer Academic Publishers.

Black, P.J. (1993). Formative And Summative Assessment By Teachers, *Studies in Science Education*, 21: 49-97.

Black, P.J. (1995). Assessment And Feedback In Science Education, *Studies in Educational Evaluation,* 21: 257-279.

Black, P. and Wiliam, D. (1998). Inside The Black Box: Raising Standards Through Classroom Assessment, *Phi Delta Kappan*, 80(2).: 139–144.

Bligh, D. (1998). *What's the Use of Lectures?* Exeter: Intellect.

Bliss, J. (1995). Piaget And After: The Case Of Learning Science, *Studies in Science Education*, 25:139-172.

Bloom, B.S. (ed.). (1956). *Taxonomy of Educational Objectives Handbook 1: Cognitive Domain,* New York: Longman, Green & Co.

Boohan, R. (2002). ICT And Communication, in S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science: Perspectives on Practice*, London: *RoutledgeFalmer*, pp 211-228.

Brookhart, S.M. (1997). A Theoretical Framework For The Role Of Classroom Assessment In Motivating Student Effort And Achievement, *Applied Measurement in Education,* 10 (2).: 161-180.

Brown, A. L. (1994). The Advancement Of Learning. *Educational Researcher*, 23(8).:4-12.

Brown, C. R. (1995). *The Effective Teaching of Biology*, London: Longman

Calderon, T.G., Gabbin, A.L. and Green, B.P. (1996). Summary Of Promoting And Evaluating Effective Teaching, *Journal of Accounting Education*, 14(3).: 367-383.

Carr, M., Barker, M., Bell, B., Biddulph, F., Jones, A., Kirkwood, V., Pearson, J., and Symington, D. (1994). The Constructivist Paradigm And Some Implications For Science Content And Pedagogy, in P. Fensham, R. Gunstone and R. White (eds). *The Content of Science*, London: Falmer, pp 147-160.

Cimer, S.O. (2004). *An Investigation Into Biology Teachers' Perceptions Of Classroom Assessment In Secondary Schools In Turkey*, The University of Nottingham, School of Education, Nottingham, Unpublished EdD Thesis.

Clements, M. A. and Ellerton, N. F. (1995). Assessing The Effectiveness Of Pencil-And-Paper Tests For School Mathematics, *Reflections,* 20(4).: 40-43.

Cosgrove, M., and Osborne, R. (1985). Lesson Frameworks For Changing Children's Ideas, in R. Osborne and F. P. Freyberg (eds). *Learning in Science: The Implications of Children's Science*, Portsmouth, NH: Heinemann, pp 101-111.

Cross, K. P. (1996). Improving Teaching And Learning Through Classroom Assessment And Classroom Research, in G. Gibbs (ed.). *Improving Student Learning: Using Research to Improve Student Learning,* Oxford, Oxford Centre for Staff Development, pp 3-10.

Crooks, T. J. (1988). The Impact Of Classroom Evaluation Practices On Students, *Review of Educational Research,* 58(4).: 438-481.

Cyrs, T.E. (1997). Visual Thinking: Let Them See What You Are Saying, *New Directions for Teaching and Learning,* 71: 27-32.

Dawe, S. (2003). Practical Work: The Universal Panacea? Available at: http://www.bishops.ntc.nf.ca/rriche/ed6620/practical.html (Accessed: 5 October, 2003).

Deboer, G.E. (2002). Student-Centred Teaching In A Standards-Based World: Finding A Sensible Balance, *Science & Education*, 11: 405-417.

Dewey, J. (1938). *Experience and Education,* New York, NY: Macmillan.

Dillon, J.T. (1990). *The Practice of Questioning,* London: Routledge.

Dori, Y. J. and Herscovitz, O. (1999). Question-Posing Capability As An Alternative Evaluation Method: Analysis Of An Environmental Case Study, *Journal of Research in Science Teaching,* 36 (4).: 411-430.

Driver, R. (1983). *The Pupil as Scientist?* Milton Keynes: Open University Press.

Driver, R. and Oldham, V. (1986). A Constructivist Approach To Curriculum Development In Science, *Studies in Science Education*, 13: 105-122.

Driver, R., Asoko, K., Leach, J., Mortimore, E. and Scott, P. (1994). Constructing Scientific Knowledge In The Classroom, *Educational Researcher*, 23 (7).: 5-12.

Driver, R., Leach, J., Millar, R. and Scott, P. (1996). *Young People's Images of Science,* Buckingham: Open University Press.

Driver, R. and Scott P. H. (1996). Curriculum Development As Research: A Constructivist Approach To Science Curriculum Development And Teaching, in D. F. Treagust, R. Duit, and B. J. Fraser (eds). *Improving Teaching and Learning in Science and Mathematics*, Teachers College Press, pp 94–108.

Duit, R. (1991). On The Role Of Analogies And Metaphors In Learning Science, *Science Education*, 75: 649-672.

Duit, R. and Treagust, D.F. (1998). Learning In Science - From Behaviourism Towards Constructivism And Beyond, in B.J. Fraser and K.G. Tobin, *International Handbook of Science Education.* Dordrecht: Kluwer Academic Publishers, pp 3-26.

Ellis, S. E. and Worthington, L. A. (1994). *Research Synthesis On Effective Teaching Principles And The Design Of Quality Tools For Educators*, Tech. Rep. No. 5, National Center to Improve the Tools of Educators, University of Oregon. Available at: http://idea.uoregon.edu/~ncite/documents/techrep/tech05.pdf (Accessed: 6 June, 2002).

Evans, R. C. and Boy, N. H. O. (1996). Abandoning The Lecture In Biology, *Journal on Excellence in College Teaching,* 7 (3).: 93-110.

Fadali, M.S., McNichols, K. and Robinson, M. (1999). Teaching Engineering To K-12 Students Using Role Playing Games, *Proceedings 1999 ASEE Annual Conference, Session 1526.*

Fensham, P.J., Gunstone, R. and White, R. (eds). (1994). *The Content of Science: A Constructivist Approach to its Teaching and Learning*, London: Falmer Press.

Gallagher, J. T. (2000). Teaching For Understanding And Application Of Science Knowledge, *School Science and Mathematics,* 100 (6).: 310-318.

Garnett, P.J. and Tobin, K. (1988). Teaching For Understanding: Exemplary Practice In High School Chemistry, *Journal of Research in Science Teaching*, 26(1).: 1-14.

Gipps, C. (1994). *Beyond Testing: Towards a Theory of Educational Assessment,* London: The Falmer Press.

Glenn, R. E. (2001). What Teachers Need To Be, *The Education Digest,* 67 (1).: 19-21

Glynn, S. and Duit, R. (1995). Learning Science Meaningfully: Constructing Conceptual Models, in S.M. Glynn and R. Duit (eds). *Learning Science in the Schools,* Mahwah, N.J.: Lawrence Erlbaum Associates, pp 1-33.

Good, T. and Brophy, J. (1994). *Looking in Classrooms,* 6th ed., New York: Harper Collins.

Good, R. and Berger, C. (1998). The Computer As A Powerful Tool For Understanding Science, in J.J., Mintzes, J.H. Wandersee, and J.D. Novak, (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 213-228

Goodrum, D., Hackling, M. and Rennie, L. (2001). *The Status and Quality of Teaching and Learning of Science in Australian Schools*. Canberra: Department of Education, Training and Youth Affairs

Griffiths, T. and Moon, B. (2000). Switching From Teaching To Learning, *BioEd 2000, The Challenge of the Next Century, Proceedings of the International Symposium,* Available at: http://archive.concord.org/intl/cbe/pdf/griffiths.pdf (Accessed: 20 August, 2002)..

Hand, B., Prain, V., Lawrence, C. and Yore, L. D. (1999). A Writing In Science Framework Designed To Enhance Science Literacy, *International Journal of Science Education,* 21,10:1021-1035.

Harlen, W. (1999). *Effective Teaching of Science. A Review of Research,* Edinburgh: Scottish Council for Research in Education.

Henderson, J. and Wellington, J. (1998). Lowering The Language Barrier In Learning And Teaching Science, *School Science Review*, 79 (288).: 35-46.

Henson, K. T. and Eller, B. F. (1999). *Educational Psychology for Effective Teaching*. Belmont, CA: Wadsworth Publishing.

Hewson G.N. and Hewson W. P. (1983). Effect Of Instruction Using Student Prior Knowledge And Conceptual Change Strategies On Science Learning, *Journal of Research in Science Teaching,* 20 (8).: 731-743.

Hewson, M. G. and Hewson, P. W. (1988). An Appropriate Conception Of Teaching Science: A View From Studies Of Science Learning, *Science Education,* 72 (5).: 597-614.

Hipkins, R., Bolstad, R., Baker, R., Jones, A., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., France, B., Haigh, M., Harlow, A. and Taylor, I. (2002). *Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education.* Wellington: Ministry of Education.

Hodson, D. (1993). Re-Thinking Old Ways: Towards A More Critical Approach To Practical Work In School Science, *Studies in Science Education*, 22: 85-142.

Hodson, D. (1996). Practical Work in School Science: Exploring Some Directions for Change, *International Journal of Science Education*, 18 (7).: 755-760.

Hwang, F., and Esquembre, F. (2003). Easy Java Simulations: An Interactive Science Learning Tool, *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning,* 5(2). Available at: http://imej.wfu.edu/articles/2003/2/index.asp (Accessed: 12 December, 2003)..

Järvelä, S. and Niemivirta, M. (1999). The Changes in Learning Theory and the Topicality of the Recent Research on Motivation, *Learning and Instruction,* 9 (Suppl. 1).: 57-65.

Johnson, D., Johnson, R. and Holubec, E. (1998). *Cooperation in the Classroom*, Boston, Allyn and Bacon.

Johnstone, A.H. (1997). Chemistry Teaching- Science or Alchemy? *Journal of Chemical Education,* 74 (3).: 262-268.

Jones, M.G. and Carter, G. (1998). Small Groups and Shared Constructions, in J.J., Mintzes, J.H. Wandersee and J.D. Novak (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 261-278.

Joyce, B., Weil, M. and Calhoun, E. (2000a). *Models of Teaching,* Boston: Allyn and Bacon.

Joyce, B., Calhoun, E., and Hopkins, D. (2000b). *Models of Learning - Tools for Teaching*, Buckingham: Open University Press

Kagan, S. (1992). *Cooperative Learning,* San Juan Capistrano, CA: Resources for Teachers

Keys, C. W. (1999). Revitalizing Writing in Scientific Genres: Connecting Knowledge Production with Writing to Learn in Science, *Science Education,* 83: 115-130.

Keys, C. W., Hand, B., Prain, V. and Collins, S. (1999). Using the Science Writing Heuristic As A Tool For Learning From Laboratory Investigations In Secondary Science, *Journal of Research in Science Teaching,* 36: 1055-1084.

Killermann, W. (1998). Research Into Biology Teaching Methods, *Journal of Biological Education,* 33 (1).: 4-9.

King, K., Shumow, L. and Lietz, S. (2001). Science Education In An Urban Elementary School: Case Studies Of Teacher Beliefs And Classroom Practices, *Science Education,* 85 (2).: 89-110.

Kirschner, P. A. (1992). Epistemology, Practical Work And Academic Skills In Science Education, *Science & Education,* 1: 273–299.

Lawson, A. E. (1988). A Better Way To Teach Biology, *American Biology Teacher*, 50(5).:569-618.

Leach, J. and Scott, P. (1995). The Demands Of Learning Science Concepts: Issues Of Theory And Practice, *School Science Review*, 76(227).: 47–51.

Lee, O. and Brophy, J. (1996). Motivational Patterns Observed In Sixth-Grade Science Classrooms, *Journal of Research in Science Teaching,* 33 (3).: 303-318.

Lemke, J.L. (1990). *Talking Science: Language, Learning and Values*. Norwood, NJ: Ablex.

Littledyke, M. (1998). Teaching for Constructive Learning, in M. Littledyke, and L. Huxford (eds). *Teaching the Primary Curriculum for Constructive Learning*, London, David Fulton Publishers Ltd, pp 17-30.

Maier, H. W. (2002). Role Playing: Structures And Educational Objectives, *The International Child and Youth Care Network*, Issue 36, Available at: http://www.cyc-net.org/cyc-online/cycol-0102-roleplay.html (Accessed: 5 July, 2004)..

McCombs, B.L. and Whisler, J.S. (1997). *The Learner-Centred Classroom and School: Strategies for Increasing Student Motivation and Achievement,* San Francisco, CA: Jossey-Bass.

McKeachie, W. (1994). *Teaching Tips: Strategies, Research and Theory for College and University Instructors,* Lexington, Miss.: D. C. Heath.

McKeon, F. (2002). Literacy and Secondary Science: Building On Primary Experience. In S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science: Perspectives on Practice*, London: *RoutledgeFalmer*, pp 199-175.

McSharry, G. and Jones, S. (2000). Role-play in Science Teaching And Learning, *School Science Review*, 82(298).: 73-82.

Millar, R. (2002). Thinking About Practical Work, in S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science: Perspectives on Practice*, London: *RoutledgeFalmer*, pp 53-59.

Millar, R. and Driver, R. (1987). Beyond Processes, *Studies in Science Education,* 14: 33-62.

Mintzes, J.J. and Wandersee, J.H. (1998). Research in Science Teaching and Learning: A Human Constructivist View. In J.J., Mintzes, J.H. Wandersee, and J.D. Novak (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 60-90.

Mintzes, J.J., Wandersee, J.H. and Novak, J.D. (1998). Epilogue: Meaningful Learning, Knowledge Restructuring And Conceptual Change: On Ways Of Teaching Science For Understanding, in J.J., Mintzes, J.H. Wandersee and J.D. Novak, (eds). *Teaching Science for Understanding: A Human Constructivist View.* San Diego, CA: Academic Press, pp 328-350

Mistler-Jackson, M. and Songer, N. B. (2000). Student Motivation And Internet Technology: Are Students Empowered To Learn Science? *Journal of Research in Science Teaching,* 37 (5).: 459-479.

Munro, J. (1999). Learning More About Learning Improves Teacher Effectiveness, *School Effectiveness and School Improvement,* 10 (2).: 151-171.

Nayar, K. A. and Pushpam, K. (2000). Willingness of Secondary School Teachers of Biology to Use Teaching Aids, *Quarterly Journal of Science Education*, 38 (4).: 1-7.

Nelson, G. D. (1999). Science literacy for all in the 21st century, *Educational Leadership*, 57 (2).: 14-17.

Novak, J. D. and Gowin, D. B. (1984). *Learning How to Learn*, Cambridge: Cambridge University Press.

Nussbaum, J. and Novick, N. (1982). Alternative Frameworks, Conceptual Conflict, And Accomodation: Toward A Principled Teaching Strategy, *Instructional Science*, 11: 183-200.

Osborne, J. (1997). Practical Alternatives, *School Science Review,* 78 (285).: 61-66.

Osborne, R. and Wittrock, M. (1983). Learning Science: A Generative Process, *Science Education*, 67 (4).: 489-508.

Osborne, R. and Freyberg, P. (1985). *Learning in Science,* Auckland: Heineman Press.

Pallrand, G. J. (1996). The Relationship Of Assessment To Knowledge Development In Science Education, *Phi Delta Kappan*, 78 (4).: 315-318.

Parkinson, J. (2004). *Improving Secondary Science Teaching*, London: *RoutledgeFalmer*

Peat, M. and Fernandez, A. (2000). The Role Of Information Technology In Biology Education: An Australian Perspective, *Journal of Biological Education,* 34 (2).: 69-73.

Piaget, J. (1960). *Play, Dreams, and Imitation in Childhood*, translated into English by C. Gattegno and F. M. Hodgson. New York, NY: Norton

Piaget, J. (1978). *Success and Understanding*, in collaboration with M. Amann ... [et al.] translated from the French by Arnold J. Pomerans, London: Routledge and Kegan Paul.

Pope, M., and Gilbert, J. (1983). Personal Experience And The Construction Of Knowledge In Science, *Science Education*, 67(2).: 193-203.

Posner, G.J., Strike, K.A., Hewson, P.W., and Gertzog, W.A. (1982). Accommodation Of A Scientific Conception: Toward A Theory Of Conceptual Change, *Science Education,* 66: 211-227.

Potari, D. and Spiliotopoulou, V. (1996). Children's Approaches To The Concept Of Volume, *Science Education*, 80: 341-360.

Prain, V. and Hand, B. (1999). Students' Perceptions Of Writing For Learning In Secondary School Science, *Science Education*, 83 (2).: 151-162.

Raghavan, K. and Glaser, R. (1995). Model-Based Analysis And Reasoning In Science: The MARS Curriculum, *Science Education*, 79 (1).: 37-61.

Renner, J. W., Abraham, M. R. and Birnie, H. H. (1985). Secondary School Students' Beliefs About The Physics Laboratory, *Science Education,* 69 (5).: 649-663.

Resnick, M. and Wilensky, U. (1998). Diving Into Complexity: Developing Probabilistic Decentralised Thinking Through Role-Playing Activities, *The Journal of the Learning Sciences,* 7(2)., Available online at http://www.ccl.sesp.northwestern.edu/papers/starpeople/ (Accessed 12 October, 2004).

Rillero, P., Cleland, J. V. and Zambo, R. (1996). Thinking, Writing And Sharing: Teacher And Student Views Of Starting Science And Mathematics Class With Open-Ended Questions, *Paper presented at the 1996 International Conference of the Association for the Education of Teachers in Science (AETS).*

Rivers, R. H. and Vockell, E. (1987). Computer Simulations To Stimulate Scientific Problem Solving, *Journal of Research in Science Teaching*, 24(5).: 403-415.

Rosenshine, B. (1997). Advances In Research On Instruction, in J.W. Lloyd, E.J. Kameenui and D. Chard (eds). *Issues in educating students with disabilities*, Mahway, N. J.: Lawrence Earlbaum, pp 197-221.

Rosenshine, B., and Stevens, R. (1986). Teaching Functions, in M. C. Wittrock (ed.). *Handbook of Research on Teaching*, New York: Macmillan, pp 376-391.

Roth, W. R. and Roychoudhury, A. (1994). Physics Students' Epistemologies And Views Of Knowing And Learning, *Journal of Research on Science Teaching*, 31(1).: 5-30.

Rowntree, D. (1987). *Assessing Students: How Shall We Know Them?* London: Kogan Page.

Sadler, D.R. (1989). Formative Assessment And The Design Of Instructional Systems, *Instructional Science,* 18: 145-165.

Saunders, W. L. (1992). The Constructivist Perspective: Implications And Teaching Strategies For Science, *School Science and Mathematics,* 92(3).: 136-141.

Schaefer, G. (1979). Concept Formation In Biology: The Concept 'Growth', *European Journal of Science Education,* 1 (1).: 87-101.

Schollum, B. and Osborne, R. (1985). Relating The New To The Familiar, in R. Osborne and P. Freyberg (eds). *Learning in science: The implications of children's science,* Portsmouth, NH: Heinemann, pp 51-65.

Scott, P., Asoko, H. and Driver, R. (1992). Teaching For Conceptual Change: A Review Of Strategies, in R. Duit, F. Goldberg and H. Niedderer (eds). *Research in Physics Learning: Theoretical Issues and Empirical Studies,* Kiel, Germany: University of Kiel, pp 310-329.

Sharan, S. and Shacher, H. (1988). *Language And Learning In The Co-Operative Classroom,* New York, Springer-Verlag.

She, H. and Fisher, D. (2002). Teacher Communication Behaviour And Its Association With Students' Cognitive And Attitudinal Outcomes In Science In Taiwan, *Journal of Research in Science Teaching,* 39 (1).: 63-78.

Slavin, R.E. (1990). *Cooperative Learning: Theory, Research, and Practice.* Englewood Cliffs, NJ: Prentice Hall.

Smith, E. L. and Anderson, C. W. (1984). Plants As Producers: A Case Study Of Elementary Science Teaching, *Journal of Research in Science Teaching,* 21: 685–98.

Solomon, J. (1993). Learning About Energy: How Pupils Think In Two Domains, *European Journal of Science Education*, 5(1).: 49-59.

Spitulnik, M.W., Zembal-Saul, C. and Krajcik, J. S. (1998). Using Hypermedia To Represent Emerging Student Understanding: Science Learners And Pre-Service Teachers, in J.J., Mintzes, J.H. Wandersee, and J.D. Novak, (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 229-260.

Stahl, R. J. (1994). The Essential Elements Of Cooperative Learning In The Classroom. *ERIC Digest,* ERIC Clearinghouse for Social Studies/Social Science Education Bloomington IN, ED370881.

Stepanek, J. (2000). Mathematics And Science Classrooms: Building A Community Of Learners, Northwest Regional Educational Laboratory U.S. Dept. of Education, Office of Educational Research and Improvement, Educational Resources Information Centre.

Stohr-Hunt, P. M. (1996). An Analysis Of Frequency Of Hands-On Experience And Science Achievement, *Journal of Research in Science Teaching*, 33 (l).: 101-109.

Strage, A. A. and Bol, L. (1996). High School Biology: What Makes It A Challenge For Teachers? *Journal of Research in Science Teaching,* 33 (7).: 753-772.

Strike, K. A. and Posner, G. J. (1985). A Conceptual Change View Of Learning And Understanding, in L.H.T West and A. L. Pines (eds). *Cognitive Structure and Conceptual Change,* New York: Academic Press.

Sunal, D. W. and Sunal, C. S. (2002). *Science in the Elementary and Middle School*, Tuscaloosa, AL: Alabama Printing Services.

Svinicki, M.D. (1999). New Directions In Learning And Motivation, Teaching And Learning On The Edge Of The Millennium: Building On What We Have Learned, *New Directions for Teaching and Learning,* 80: 5-27.

Tamir, P. (1983). Inquiry And The Science Teacher, *Science Education*, 67 (5).: 657-672.

Taras, M. (2002). Using Assessment For Learning And Learning From Assessment, *Assessment & Evaluation in Higher Education,* 27(6).: 501-510.

Tobin, K. (1993). *The Practice of Constructivism in Science Education*. Washington DC:AAAS Press.

Tobin, K. and Gallagher, J. (1987). What Happens In High School Science Classrooms? *Journal of Curriculum Studies*, 19 (6).: 549-560.

Tobin, K., Tippins, D.J. and Gallard, A.J. (1994). Research On Instructional Strategies For Teaching Science, in D.L. Gabel (ed.). *Handbook of Research on Science Teaching and Learning,* New York: Macmillan, pp 45-93.

Tomic, W. (1994). Training Programs In Research Into The Effectiveness Of Teacher Behaviour, *Journal of Education for Teaching*, 17 (2).: 181-187.

Treagust, D. F., Duit, R. and Fraser, B. J. (eds). (1996). *Improving Teaching and Learning in Science and Mathematics*, New York: Teachers College Press.

Trowbridge, J. E. and Wandersee, J. H. (1998). Theory-Driven Graphic Organisers, in J.J., Mintzes, J. H. Wandersee, and J.D. Novak, (eds). *Teaching Science for Understanding: A Human Constructivist View,* San Diego, CA: Academic Press, pp 91-131.

Trowbridge, L. W., Bybee, R. W. and. Powell, J. C. (2000). *Teaching Secondary School Science*, Upper Saddle River, NJ: Merrill / Prentice Hall.

Tytler, R. (2002a). Teaching For Understanding In Science: Student Conceptions Of Research, And Changing Views Of Learning, *Australian Science Teachers Journal,* 48,3:14-21.

Tytler, R. (2002b). Teaching For Understanding In Science: Constructivist/Conceptual Change Teaching Approaches, *Australian Science Teachers Journal,* 48 (4).: 30-35.

Tytler, R. Waldrip, B. and Griffiths, M. (2004). Windows Into Practice: Constructing Effective Science Teaching And Learning In A School Change Initiative, *International Journal of Science Education*, 26 (2).: 171-191.

Van Driel, J. H. and Verloop, N. (1999). Teachers' Knowledge Of Models And Modelling In Science, *International Journal of Science Education,* 21(11).: 1141-1153.

Vosniadou, S. (1997). On the development of understanding of abstract ideas, in K. Harnqvist and A. Burgen (eds). *Growing Up with Science,* London: Jessica Kingsley.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes,* Cambridge, M A: Harvard University Press.

Walberg, H. J. (1991). Improving School Science In Advanced And Developing Countries, *Review of Educational Research*, 61: 25-69.

Watts, M. (1994). Constructivism, Re-Constructivism And Task-Orientated Problem-Solving, in P. Fensham, R. Gunstone and R. White (eds). *The Content of Science*, London: Falmer, pp 39-58.

Watts, M., Gould, G. and Alsop, S. (1997). Questions Of Understanding: Categorising Pupils' Questions In Science, *School Science Review*, 79 (286).: 57-63.

Wittrock, M., (1994). Generative Science Teaching, in P. Fensham, R. Gunstone and R. White (eds). *The Content of Science*, London: Falmer, pp 29-38.

Wragg, E.C., Bennett, S.N. and Carr. C.G. (1989). Primary teachers and the National Curriculum, *Research Papers in Education*, 4 (3).: 17-37.

Yager, R.E. (1995). Constructivism And The Learning Of Science, in S.M. Glynn and R. Duit (eds). *Learning Science in the Schools. Research and Reforming Practice,* N.J.: Lawrence Erlbaum Associates Inc., Publishers, pp 35-58.

Yates, G. C. R. and Yates, S. M. (1990). Teacher Effectiveness Research: Towards Describing User-Friendly Classroom Instruction, *Educational Psychology,* 10(3).: 225-228.

Yip, D. Y. (1998). Children's Misconceptions On Reproduction And Implications For Teaching, *Journal of Biological Education,* 33 (1).: 21-26.

Yip, D. Y. (2001). Promoting The Development Of A Conceptual Change Model Of Science Instruction In Prospective Secondary Biology Teachers, *International Journal of Science Education*, 23 (7): 755-770.