South African Journal of Education
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Vol 25(4)239–246

Improving thinking skills in science of learners with (dis)abilities

Nilly Galyam and **Lesley Le Grange**
llg@sun.ac.za

We reflect on two cycles of inquiry involving the explicit teaching of thinking skills to learners with learning (dis)abilities and how these skills may be bridged to the learning of science. The purpose of the research was to critically explore to what extent teaching science using selected Instrumental Enrichment (IE) instruments can: contribute to the development of science thinking skills in learners with special needs; contribute to the transfer of thinking skills to other learning areas; and provide the learners with an interactive science programme that is suitable to their particular learning needs? We report improvement in learners' thinking skills due to the intervention programmes but also point out that evidence of transferability of thinking skills from science to other learning areas is inconclusive.

Introduction

Living in an era of change and development, we are constantly challenged by new scientific information and technological developments in a complex social environment. Part of being able to adapt to this rapidly changing environment depends to a large extent on the ability to think adequately and reach decisions based on reasoning, analysis and synthesis of information. Effective use of thinking skills and processes affects every aspect of our lives in social, professional or day-to-day contexts. Therefore, one of the main goals of educational systems nowadays is emphasising the development and improvement of, and instruction in, thinking skills and processes throughout the curriculum.

Children's cognitive development depends on two main domains: biological and social (Gindis, 1995:78; Feuerstein *et al.*, 1981:272). Pre-determined, genetic factors and some congenital factors affect the potential of cognitive development. However, children do not develop in isolation but in their surroundings and in specific social contexts. The interaction with their close social environment affects their cognitive and psychological development as well (Wells, 1999:6; Karpov & Haywood, 1998:27). Many learners are exposed to an environment that helps them develop specific cognitive skills, which in turn allows them to become independent learners (Feuerstein & Feuerstein, 1991:10). These learners continue to learn throughout their lives using direct exposure to stimuli as opportunities for learning. This is done by mechanisms of assimilation and accommodation which Piaget described and which have become known as the 'constructivism theory' (Feuerstein & Feuerstein, 1991:9; Ormrod, 1995:36).

On the other hand, there are learners who develop differently. The etiology of learners with special needs suggests that either biological or social factors or the combination of the two can lead to difficulties in learning (Haywood, 1993:27). Some learners may struggle to learn on their own and may not be able to benefit from direct exposure to stimuli, which may lead to delayed development or even lack of cognitive functions (Feuerstein & Feuerstein, 1991:10).

In the last three decades more evidence has accumulated suggesting that thinking skills and processes and cognitive functions can be mediated and developed by learners with a wide range of abilities. (Costa, 1991; Costa, 2004; De Bono, 1993; Feuerstein *et al.*, 1981; Frankenstein, 1979; Gindis, 1995; Kozulin & Presseisen, 1995). Vygotsky, Feuerstein and others theorised on the etiology of learners with special needs and the ways to assist them (Feuerstein *et al.*, 1981; Feuerstein & Feuerstein, 1991; Haywood, 1993; Gindis, 1995; Kozulin & Presseisen, 1995). Intervention programmes to develop thinking skills and processes started to emerge. Increasingly more educators believed that something could be done to improve cognitive functions and that thinking can be taught and developed intentionally. Studies that evaluated these intervention programmes were conducted, providing evidence for possible changes in learners' ability to solve problems and apply thinking skills (Cotton, 2000; Sternberg & Bhana, 1986; Narrol *et al.*, 1982; Shayer & Adey, 1992a; 1992b). What characterised most of these intervention programmes was the need for special effort, high level of motivation and focused intention on the educator's part so as to help learners develop thinking skills and to fulfill their potential.

Science education was dominated for many years by the transmission of content knowledge to learners, an approach that was found to be suitable mainly for learners with above average abilities, but shown to be less suitable for learners with average or below average abilities (Wellington, 1989:8). This, together with other reasons, influenced a change in science education, which was characterised by placing greater emphasis on the teaching of thinking skills and processes and became known as the 'process-led' approach. Some argue that skills and processes, especially if they can be transferred to other learning areas, are more relevant to learners than transmitting factual content to them, for example (Screen, 1986:13-14; Costa, 2004:1). Others argue that skills and processes are more accessible to a much wider range of ability than traditional approaches to science education (the transmission of facts) would seem to allow (Jenkins, 1989:42; Screen, 1986:15).

The aim of the research was to reflectively teach specific skills and processes that are known to be representative of problem-solving activity in science (Gange, 1970 in Shaw, 1983) to learners with special needs, using some instruments from a specific intervention programme known as Instrumental Enrichment (Feuerstein, 1980). Learning the skills explicitly in science programmes may help learners to transfer them to other disciplines as well. These skills and processes can serve — in Millar's (1989) terms — as "general approaches which we all use all the time in making sense of the world". More specifically, this article intends to document a praxiological account of how the nexus between an alternative approach to science teaching and the special needs of learners is played out in two South African classrooms. The study is pertinent to South Africa because recent policies, on the curriculum, inclusive education and disability, mandate that science processes/skills be taught to all school learners.

Research methodology

Approach

Action research was used in the study for the purpose of improving the teaching of science to learners with special needs and to involve them actively in the teaching/learning process. Evaluation action research is part of applied research and more specifically, it is part of programme evaluation research. In applied research the intention is to improve practice by directly involving those within the educational process in reflecting upon, evaluating and perhaps changing their practice (Hitchcock & Hughes, 1995:102). Applied research manifests itself in the form of planned social intervention, or as an action taken within a social context for the purpose of producing some intended result (Babbie & Mouton, 2001:338-9).

One form of evaluation action research is the approach of research-based teaching and self-evaluation suggested by Stenhouse (1975; 1983), in which an emphasis is placed on developing the practical skills and understandings necessary for those involved in programme assessment as well as to evaluate their own practice (Potter, 1999:220). In evaluation programmes the evaluator studies an educational activity *in situ*, or as it occurs naturally without constraining, manipulating or controlling it (Worthen & Sanders, 1987 in Hitchcock & Hughes, 1995:35).

Two cycles of inquiry took place with different sets of learners over a period of two years — Grade 6 learners in the one year and Grade 5 learners in a following year. Practical constraints prevented the teacher-researcher (NG) continuing with the Grade 6 learners in the second year because the Grade 6 learners returned to mainstream schools in the following year. However, the first cycle of inquiry was useful in informing the second cycle of inquiry with regard to NG's mediational competences in particular. Also, we go along with McTaggart (1993:21) when he writes:

> It is of course a mistake to think that slavishly following the 'action research spiral' constitutes 'doing action research'. Action research is not a 'method' or a 'procedure' but a series of commitments to observe and problematise through practice the principles for conducting social inquiry described in summary here... In my view, Lewin was simply trying to suggest that action research was different from traditional empirical-analytical and interpretive research in both its dynamism and its continuity with an emergent practice.

Context

The study took place at a private school, in a suburb of Cape Town, for learners with special needs. The mission statement of the school is *to help learners with special needs to progress in a safe, encouraging and structured environment by recognising the unique learning styles of the children and to provide him/her with alternative and focused learning methods*. The school has small classes, with a maximum of 12 learners in every classroom, and has about 80 learners in total, with ages ranging from 6 to 15. The school caters for learners with learning disabilities such as Attention Deficit Hyperactive Disorder (ADHD), mood disorder, dyslexia, among others. The school employs remedial teachers, psychologists, speech and occupational therapists, and physiotherapists who help to carry out multidisciplinary interventions.

Sampling

Two classes of 12 Grade 6 learners and 12 Grade 5 learners from the school served as the purposive sample. Purposive sampling or judgement sampling uses the judgment of an expert in selecting cases or when cases are being selected with a specific purpose in mind, (Bernard, 2000:176; Newman, 2003: 213; Terre-Blanche *et al*., 1999:281). This type of sampling suited our needs because of several reasons:

- We were concerned with the individual progress of learners with special needs, rather than the sum score from the class or the school;
- Class sizes were small;
- Grades 5 and 6 learners should be able to develop these thinking skills and processes (Hester, 1994; Department of Education, 2002);
- IE is a programme suitable for learners with special needs (Arbitman-Smith & Haywood, 1980; Feuerstein, 1980); and
- Using two different grades allowed us to embed the intervention programme into two different curricula in science and by that increase the validity of the programme.

Techniques/methods and data production

Eighteen lessons were designed in both intervention programmes around science content knowledge from the science textbook, as recommended by the classroom teacher, one for the Grade 6 learners and the other for Grade 5 learners. (Cadle *et al*., 1995a; Cadle *et al*., 1995b). The thinking skills that were chosen are known to be representative of problem-solving activities and can also be used in everyday life ((Gange, 1970 in Shaw, 1983). These skills are in line with the list of thinking skills and processes for Grades 5 and 6 as recommended for Natural Sciences Learning Area of the Revised National Curriculum Statement (Department of Education, 2002). The thinking skills and approaches chosen for the Grade 6 learners for the period of one term were: six-steps approach to planning, following instructions, measuring, inferring, comparing, classifying and experimenting. 'Solutions' and 'Food and Feeding' were the science content knowledge which were used as a vehicle to practice the thinking skills. For the Grade 5 learners the following skills and approaches were selected as thinking skills for the period of one term: six-steps approach to planning, measuring, comparing, classifying and experimenting. 'Phases of Matter' and 'Water' served as the science content knowledge. Lessons were given twice a week for a period of one hour. Learners in Grade 6 answered 7 questionnaires regarding their feelings and understanding of science skills and content every alternate lesson in the first cycle, and Learners in Grade 5 answered 5 questionnaires in the second cycle. The teacher-researcher's and permanent teacher's direct observations were augmented with a short collaborative reflection on the lesson, highlighting its main advantages and disadvantages. All the lessons were videotaped, viewed, transcribed by the teacher-researcher and analysed after every lesson. Learners of both Grade 5 and Grade 6 completed four quizzes (every two weeks) and all classroom task-sheets were handed in to the teacher-researcher for purposes of evaluating learner's achievements formatively and summatively. Each reflection on a lesson was intended to bring new insights and lead to the improvement of the next lesson. Two semi-constructed interviews with the permanent teacher were conducted at the end of each major cycle of inquiry and were concerned with the effectiveness of the programme, the learners' progress, and his critique on the programme and lessons as such. The teacher-researcher kept a personal journal to record her reflections and the class teacher took field notes based on his observations. The array of research techniques employed in the study enhanced the trustworthiness of the research findings through triangulation of data and data production techniques.

Data analysis

Data analysis consisted of a few steps followed as a sequence for each lesson. At the end of each sequence the lesson as a whole was evaluated focusing on individual learners and the teacher-researcher. The focus was on learners' progress in terms of use of thinking skills and processes, use of vocabulary and understanding of science concepts and content knowledge, and on the abilities of the teacher-researcher to mediate, use of bridging and mediation of principles and rules, teaching style and questioning. This is a more detailed description of each step taken:

- The teacher-researcher watched every videotaped lesson and transcribed it, indicating who the speakers are and what the different activities were. This idea was adapted from Heath and Hindmarsh (2002), who further explain that the transcription does not replace the video recording as data, but rather provides a resource through which the researcher can begin to become more familiar with details of the participants' conduct (Heath & Hindmarsh, 2002:109). The transcriptions were recorded in detail, quoting as accurately as possible learners' responses and that of the teacher-researcher. The information was written on record cards that served as devices to enable the teacher-researcher to identify particular actions and to preserve a rough record of what had transpired.
- The second stage was to combine new themes that emerged in the first step with previous ideas and feelings that the teacher-researcher produced from the reflection notes of both the permanent teacher and her own. This information was used mainly to develop a wider evaluation of the lesson.
- The third step was to construct a personal evaluation of each learner, analysing his/her performance in the classroom tasks and quizzes, combining information from questionnaires, and picking up indications of progress as reflected on the record cards of the transcribed videos. Units of meaning were produced such as a quote, a micro-change in behaviour or an achievement that might have some meaning. This idea was adapted from Maykut and

Morehouse's (1994:134) description of the comparative method of data analysis. They used the units to compare different responses from a large-scale study, whereas in this instance the teacher-researcher worked with only 12 learners. Therefore instead of connecting relevant units from different participants to create a category, we used the units of meaning to build a record of changes in progress, attitudes and characteristics of every individual learner. The accumulative data reflected learners' experiences. These were also recorded on cards. The results of all data produced from different sources for each learner were available on one record card.

- The fourth step was to evaluate the teacher-researcher's own progress as a teacher, as perceived from watching the video, the teacher-researcher's own reflections at the end of each lesson, and the reflections she undertook collaboratively with the classroom teacher. A summary of the evaluation of the teacher-researcher was recorded on a record card.
- The last step was to evaluate the learning programme outcomes that the teacher-researcher determined prior to the commencement of the programme in the light of the data produced in steps 1 to 4.

Findings of two cycles of inquiry

The findings will be organised in relation to the following themes: the development of science thinking skills and their transfer, acquisition of content-knowledge and the suitability of the intervention programme to the learner's needs. Each theme was constructed from data produced from different sources using various techniques, which were merged together to throw light on the intervention programme's effectiveness. Quizzes and worksheets were used to reflect on learners' scholastic achievement and questionnaires were administered for reflection on learners' opinions and feelings. These were supplemented by the classroom teachers' reflection on different issues, as they transpired from formal and informal conversations between the classroom teacher and teacher-researcher as well as from the interviews with him.

Acquiring thinking skills and processes and their transfer

The Grade 5 learners showed an adequate use of the thinking skills they learned. The first skill they used was the 'six-step approach to plan' (from the Instrumental Enrichment (IE) instrument 'Organisation of Dots') (Hoffman & Feuerstein, 1988a:18), in which the learners had to apply to novel tasks, including planning a scientific investigation. The learners defined the goal of their task and gathered information related to it, identified a possible frame of rules, which might guide their work, and worked according to it. They were generating strategies (sometimes more than one) to solve their problem(s), and found ways to check if their strategy had worked. The learners could apply the 'six-step approach' to planning successfully to tasks administered to them in the context of science learning. For example, in the last quiz that the learners completed, they were requires to help a zoo manager to create a giraffe with black and white stripes. 8/10 defined their goal, 9/10 knew where to look for information, 7 came up with a strategy to create a giraffe with black and white stripes, 6 of whom suggested different types of painting and **N** suggested injecting DNA into its skin. 6/10 indicated a relevant rule and 7/10 reported that they intend to check their work after experimenting, by looking at the outcomes and comparing it to the hypothesis. The classroom teacher reported that learners could apply this approach to tasks of other learning areas after they had learned the skill in the science classroom.

Comparative behaviour

Comparative behaviour, according to Feuerstein, is a mental abbreviation of a motor process in which two elements are superimposed in order to find the points they share and the way they differ. Inducing comparison initially involves making the individual perceive and focus on two or more objects or events (Hoffman & Feuerstein, 1988b:1-2). The principles of comparing were mediated to and practiced by the learners, using the IE instrument Comparisons (Hoffman & Feuerstein 1988b). The learners, in turn, started explaining their choice of answer according to these principles.

One example of a successful application was that the learners had to define what was common between two pictures of the same boy; one with eyes opened and the other with eyes closed. **P** explained to **R** why his answer "the same boy" is better than **R**'s answer: "both are smiling" saying: "there are a lot of tiny bits that look the same that are common but they [referring to the faces] look like exactly the same face and this is the big [common] one". Another example was when the learners compared two pictures of apples, in which one was small and the other one big, **J** said that the main common thing between the apples is "both the big apple and a small apple have the same taste". **Tk** did not agree with **J** saying: "I don't agree because what is common about them is that they are both the same fruit" and **R** added: "they are both apples".

Later in the term the use of the Venn diagram was mediated to the Grade 5 learners. First they had to compare water and milk by using the Venn diagram. The learners ended with a diagram as illustrated in Figure 1.

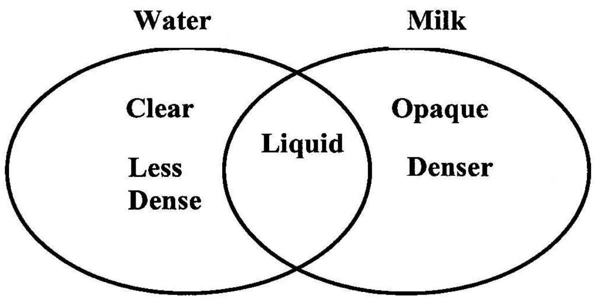

Figure 1 Venn diagram produced by Grade 5 learners

In the last questionnaire they completed the learners had to use the Venn diagram to compare solids and gases, where 7/11 applied it correctly.

Classification

Classification can be very useful to organise new as well as known information into groups, which in turn requires less memory storage and can be handled easily. When we classify items into groups, we use the similarities to group them and use their differences to sub-divide them again. Classification depends on the task and the variety of parameters can lead to different results in terms of grouping (from the IE instrument Categorization) (Hoffman & Feuerstein, 1988c).

The principles of classification were mediated to the Grade 5 learners, and they demonstrated an ability to use the linear diagram, which was introduced to them for the first time, when classifying different things into groups in basic tasks and in a science learning context. For example, the learners had to classify pictures of various types of transportation into categories using the linear diagram. They used the transport medium of use (air, land and sea) as a principle, and some also sub-divided them according to their function (military, public or recreation), manifesting adequate use of the skill. Learners were invited to the board to illustrate their linear diagram. We compared the different diagrams and discussed the sub-divisions. Later, the learners had to apply the principles of classification in a science learning context in a few tasks we adopted from the year's science books and adjusted to include classification tasks (Cadle *et al.*, 1995b; Clacherty *et al.*, 1998). The tasks required gathering new information and organising it in a hierarchical way according to parameters we specified. For example, in one task they had to divide pictures presenting the use of solid water in different situations. The learners had to discuss each case and decide if it was useful or not, using the linear diagram. In the other task the learners had to divide sources of water into human-made or natural. In the last quiz completed, the Grade 5 learners had to classify items according to their phase of matter. 10/12 divided items according to their phase of matter and all the learners used the linear diagram correctly. In addition, they used the linear diagram in other learning areas (phonics and mathematics) and were able to apply the principles as mediated to them.

Given the fact that the Grade 5 learners were younger, and had less science knowledge and strategies to solve problems, than the Grade 6 learners, they coped more than adequately with the science content knowledge and skills — so much so that the classroom teacher considered the cycle of inquiry with them to be more successful. In terms of the learning outcomes specified for the learners' level, the Grade 5 learners demonstrated that they could plan investigations effectively and conduct experiments to some degree. They classified effectively and recalled information meaningfully when required and could apply this in solving problems which had not been taught explicitly. The abilities demonstrated by the learners are all reflected in the learning outcomes specified in the RNCS (2002) for the intermediate level (Grades 4–6) (Department of Education, 2002:30).

The Grade 6 learners had a better starting level on all the thinking skills we chose to teach and manifested a mastery of the skills and processes to a greater extent than the Grade 5 learners. They picked up the principles faster and applied them more accurately, demonstrating an adequate ability to use them (for details see Galyam & Le Grange, 2003).

Comparative behaviour

After mediating the principles of comparison from the IE instrument (Hoffman & Feuerstein, 1988b:1-2) learners had to find the similarities and differences between pictures of objects and people. After completing the task, we discussed each frame and mentioned a number of parameters that objects could differ in, for example, size, orientation, colour, shape, texture, smell, taste, etc., and the fact that not all parameters are relevant to all the things we compare. In the following task the learners had to compare two solutions they prepared according to instructions the teacher-researcher gave, and had to find as many parameters as possible when looking for similarities and differences. Learners had to give an example of one parameter and indicate if it was similar or different. We ended up with the information in Table 1, which describes the two solutions.

Table 1 Description of two juice solutions in terms of similarities and differences

Parameter	A	B	Same	Different
Amount of water in ml	100	100	✓	
Water level in the beaker	Until 100 ml	Until 100 ml	✓	
Shape and size of container	Beaker	Beaker	✓	
Amount of juice powder in teaspoons	1	2		✓
Type of powder	'Clifton'	'Clifton'	✓	
Colour	Light orange	Darker orange		✓
Smell	Less strong	Stronger		✓
Taste	Less sweet	More sweet		✓

In the next lesson the teacher-researcher mediated the usage of the Venn diagram as a way to organise information concerning similarities and differences between things. To demonstrate the usage of the Venn diagram, we used the information on the solutions from Table 1 from the previous lesson. In the third quiz a week later they had to organise information in a table into the Venn diagram and 8/11 applied it successfully. In the last quiz, four weeks later, learners had to compare a leopard and a giraffe using the Venn diagram. All the learners (11) successfully used the Venn diagram, either describing the animals on a more concrete level, such as long/short neck/legs, etc. or writing more abstract parameters such as herbivore/carnivore, etc.

The learners completed a questionnaire about comparative behaviour; many of the learners agreed or strongly agreed on:

- I will be able to use comparisons in other classes. (8/11)
- I think I know how to use comparisons in science. (10/11)
- When I compare, I look for what is the same and what is different. (10/11)
- I automatically make comparisons when I work. (7/11)
- It is very hard to compare solutions. (7/11 disagreed or strongly disagreed)

Classification

The principles of classification were mediated to the Grade 6 learners over 3 lessons using the IE instrument Categorization (Hoffman & Feuerstein, 1988c). The linear diagram was used to classify various objects according to the lesson content. After three lessons of practical application the learners completed their last quiz in which they needed to classify a list of words according to the principles they had learned, such as in the following example:

> Classify these living things according to the principles we have used: Organisms, fungi, trees, animals, herbivores, omnivores, snake, bacteria, mushroom, flowers, plants, carnivores, humans, bushes, tiger, butterfly.

Eight out of 11 learners successfully performed this task, which required correct usage of the principles of classification, identification of the categories, systematic search, looking at the number of spaces as clues and application of knowledge.

In an open lesson at the end of the term, the learners were asked: "What was the most interesting thing we learned?"

Sa replied: "*classification which was a bit hard but challenging ...*"
Da said: "*classifying and learning about the animals ...*"

The Grade 6 learners showed an increased use of vocabulary related to the different skills, communicating precisely what guided their work and how they arrived at a specific conclusion. Increasingly, learners applied the principles to novel tasks as the term proceeded and it seemed that learners were developing self-awareness of their own thinking. The Grade 6 learners also showed an increase in creativity, specifically in fluency and originality as discussed elsewhere (Galyam & Le Grange, 2003). When hypothesising, they were critical about the strategies and ideas they offered and could explain their choices, realising that these ideas could be wrong and that they needed to be proved first. Some examples are given:

Cht: '*... not to use two experiments at the same time because maybe one of them works but you don't know which it is ... only one strategy at a time ...*' (lesson 3)

Nig: '*may be the cow is sick, we have to have more cows, more then one ...*' (lesson 3)

K: '*you have to compare before and after so you will know if there is a difference*' (lesson 5)

Tm: '*By defining my goal and gathering data, I discovered that ... by using what he is wearing and the objects around him, he is a chemist or a scientist*' (Lesson 2)

Cht: '*We have to define our goal of what we are supposed to make. We had to make a liquid but we didn't know what was it ... we looked at what we had and gathered data: we had water and powder and we had to do something ... to put them together ... what strategy shall we use: should we measure with the jug or with the measurement cylinder ... where shall we start — I followed the instructions ... what were the rules: be accurate ...*' (Lesson 3)

Sa: '*We looked at what we have: we have a measurement cylinder and a beaker, water and spoon. Where shall we start? By adding the water and powder. We mixed it afterwards*' (Lesson 4).

K: '*we don't know if our suggestion is right and because of that we are going to check*' (Lesson 8)

The Grade 6 learners manifested most of what is expected at the end of the intermediate phase, namely, planning, conducting and evaluation of scientific investigations, collecting data and communicating them efficiently (as required by Department of Education, 2002: 29-30). Moreover, they recalled meaningful information and applied it correctly on novel tasks. The learners compared, classified, hypothesised, inferred and controlled variables in an efficient way. All of these processes and skills are in line with what is specified in the RNCS (Department of Education, 2002:13-14), as expected at the end of the intermediate phase (Grade 6). What may be suggested is that this approach could facilitate learners' abilities to develop the thinking skills and processes reflected in the critical and learning outcomes defined in the RNCS (2002).

In summarising these achievements, it was evident from the data that the learners made adequate use of the thinking skills and processes in the learning of science and in some content-free tasks. Nevertheless, we do not claim that we taught the thinking skills and processes from scratch, but rather made some aspects of these skills more explicit to the learners, helping them to become aware of certain principles and providing the learners with opportunities to practise them. As mentioned, we mediated situations so that the learners could apply and gain mastery in the use of various thinking skills and processes, as well as providing opportunities to question, make mistakes and discuss these principles. Moreover, learners were provided with opportunities to successfully apply them to novel, similar and different kinds of tasks. Our findings suggested an improvement in applying thinking skills and processes after explicit teaching of the principles of skills and processes to context-free tasks, and later bridging them into science contexts. But, we turn now to a more detailed discussion around themes constructed from the literature and data.

Discussion

Content

When referring to thinking abilities, questions regarding content knowledge must be considered, because we are required to adapt to and evolve in an ever-changing world. Almost by definition, understanding how the world functions and operates demands knowledge as well as skills. In other words, to be able to predict certain phenomena, to be able to infer, hypothesise, plan, etc., one must know the discipline's rules, principles and theories that guide them, which involves content knowledge. Here we would like to clarify that, although we integrated processes and skills, based on the strong belief of their importance, we did not neglect to teach science content knowledge, which enabled the learners to use the skills in an appropriate context. In both cycles acquisition of knowledge by the learners occurred to a greater extent than predicted by the classroom teacher. This indicates that placing the emphasis on thinking skills does not necessarily mean that less content would be taught (as was the case with the Grade 6 intervention programme) or that learners will not demonstrate an understanding of the science concepts, as was the case in both cycles. With the Grade 5 learners the teacher-researcher planned to teach less content knowledge, bearing in mind that this balance between content and skills can be optimised within a longer time frame. The teacher-researcher taught only a bit more than half of what is recommended for a normal term in mainstream schools for Grade 5 learners. Nevertheless, the classroom teacher regarded this amount of content knowledge as more than adequate for these learners. The important thing is that the learners, although displaying short memory spans (problems of recall and focus), showed a good understanding of science concepts and content knowledge. The learners in both Grades 5 and 6 could recall meaningful information and apply it to novel tasks, which reflect some of the learning outcomes expected of this age level (Department of Education, 2002:29-30).

Bridging

Bridging or 'transcendence', as Feuerstein refers to it, is 'the orientation of the mediator to widen the interaction beyond the immediate and elementary goal, and creates in the mediatee a propensity to enlarge his [*sic*] cognitive and effective repertoire of functioning constantly' (Feuerstein & Feuerstein, 1991:21-22). This is achieved by explicit teaching of the basic skills and then linking/bridging/associating them to different situations where the skills can be applied, and also to encourage the learners to generate similar occasions/situations where they can use them (Haywood, 1993:35). Since Feuerstein's intervention programme is intended to be taught as a programme on its own (i.e. not integrated to a specific discipline), the bridging should be to events and circumstances that are familiar to the learners, should be elicited from the learners, and should be simple and straight forward (Haywood, 1993:35)

The teacher-researcher taught specific skills and processes within a specific science context, and bridging between the skills and the tasks/situations where they can be applied was almost an immediate thing. For example, after mediating the principles of comparisons, the Grade 6 learners had to compare different things first in everyday life and then in science contexts. They compared various pictures of objects and people, stating what is common and what is different between them. Then they compared various solutions they had prepared and defined the criteria they used to compare them, such as colour, smell, taste, and so on. The Grade 5 learners compared the classroom teacher and the teacher-researcher according to different criteria they chose to compare them, for example, marital status, height, hair, colour, etc. Further, they compared particles of water in different phases and different properties of liquids. These are all examples of the bridging of thinking skills and processes to different contexts. We found in both cycles that after the teacher-researcher initiated bridging between the basic skill or process to scientific problems as well as other contexts, the learners manifested an ability to use and apply the skills to novel tasks. Bridging is a necessary process, which takes the learners beyond the level of the basic skill or approach, to a higher level of where the skill can be applied, and by so doing creates a nexus between the two.

Transfer

The bridging process is crucial for transfer to happen, since without the bridging process the basic skill or approach is isolated from any applicable context. However, this is not to suggest that whenever a skill or a process is bridged that transfer will always occur. We find that the bridging process can raise the likelihood that transfer could happen, but there is no guarantee that it will.

Without suggesting that the bridging abilities of the teacher-reseracher were fully developed, since her experience as a mediator was relatively limited, tying the ability to bridge and the transferability of the skills to other learning areas is problematic, in the sense that bridging does not necessarily indicate that transfer of the skills to other learning areas will occur. The claim that these two aspects, namely, bridging and transferability, are strongly linked removes the ability to check objectively the transferability of thinking skills to other learning areas, because the ability to bridge is subjective and not necessarily quantifiable. It may be difficult or even impossible to deduce from a situation in which transfer did not occur or was manifested only to a certain extent in other learning areas, which conditions interfered, since this lack of transfer could be due to various reasons. Indeed, in some cases as reported, transferability occurred to some extent and on some other occasions it did not, and it is difficult to say which factors are responsible for making transfer possible, including bridging.

Our evidence of transfer of specific skills within the same subject matter but to novel tasks on various occasions are in line with McPeck's claim of transferability of particular approaches to particular situations, such as when using the principles of classification for novel content (McPeck, 1990:14). In addition to that, the Grade 6 learners reported in a few (3) questionnaires that their confidence in using the skills in other learning areas increased. The classroom teacher reported in both interviews that he feels there were 2–3 occasions in each cycle of inquiry where he recognised transfer of the skills to other learning areas. The classroom teacher's and the learners' reports might indicate that there was some transferability of thinking skills and processes to other learning areas. Some examples were manifested in the phonics and mathematics lessons in which they recognised the skills and used them efficiently. This is in line with what Bransford *et al.* (1986) claim, namely that 'blind' instruction, in which the teaching of thinking skills and processes, or their transferability are implicit, usually does not lead to transfer of thinking skills to new tasks. However, when the instruction focuses on helping learners become problem solvers who learn to recognise and monitor their approaches to particular tasks, transfer is more likely to happen (Bransford *et al*., 1986:69-70). This also suggests that the explicit teaching of thinking skills and processes might be more potent in terms of transfer of these to other learning areas. Although we cannot provide solid evidence of transferability to other learning areas, there appears to be some basis to believe that transfer can occur as a result of this type of teaching.

According to our experience in two cycles of inquiry, and along with what seemed to transpire from the literature, for transfer to occur, one needs to mediate the principles of various thinking skills and processes explicitly, and bridge them to a wider science context and to some extent also to other areas of the curriculum. Under these conditions, it appears that transfer of thinking skills and processes occurs within the subject matter and may occur to some extent also to other learning areas.

Mediation

Mediated Learning Experience (MLE) is a theory of learning, where the teacher, a parent or any other character in the child's life directs the child's attention to a particular object or situation, and assists him or her to interpret and gain meaning from the surrounding environment (Feuerstein *et al*., 1981:271). Mediation, according to Feuerstein, has to include at least three main characteristics out of the twelve he mentions, namely, Intentionality, Meaning and Transcendence. Feuerstein claims that the best way to evaluate the mediational quality of an interaction between a teacher and learners is to 'detect how different is the mediated event from the regular one, how different is the speech of the teacher when he [*sic*] merely transmits an instruction from when he [*sic*] mediates it to the students' (Feuerstein & Feuerstein, 1991:18). Being able to mediate requires a shift on the teacher's part from the traditional teaching style, with its emphasis on the transmission of knowledge and its recall, to a mediational teaching style, which is quite different in many respects. Successful mediation requires the mediator to ensure that the learner is aware of and understands what s/he is going to do, why s/he is doing it, and that the act has a value beyond the here and now (Burden & Florek, 1989 in Head & O'Neill, 1999). In other words, teacher-mediators help the learners become metacognitively aware of the meaning behind specific learning material, why it is important and how to go about it. Teachers who practise what is known to be representative of good mediation, according to Haywood (1993), 'help children reduce the number and complexity of stimuli and help the learners to focus on its relevant aspects. They repeat exposure to important stimuli, perceive understanding of similarities and differences, sequential relationships, dimensionality, antecedents and consequences, ... and grasping the concept of generalisability of experience to new situations' (Haywood, 1993:31).

At the end of the first cycle of inquiry, the classroom teacher commented on the teacher-researcher mediational abilities:

> *You listened very carefully and as we spoke and reflected on the lessons, from lesson one onwards, initially there wasn't mediation, later the mediating came more and more and played a greater role*. (Interview script, 2002:8)

The video material confirmed an increase in mediating incidents and increased use of opportunities to mediate during the lesson. The teacher-researcher mediational teaching style had started to take shape and was evident in dialogues in which learners could express the ways in which they thought, challenging right as well as wrong answers, requesting justifications for both, placing an emphasis on meaning, principles and rules, and of course the use of bridging. The teacher-researcher was following the mediational teaching approach during both cycles and had continuous support from the IE trainer. The teacher-researcher was trying to provide the meaning behind a skill or a process she chose to teach (i.e. by explaining the importance of the skill or process, how and where it can serve as a useful tool and so on). Also, she was mediating why we learn specific content, in what ways it affects our life, etc., all of which is part of mediating the meaning behind the content. The teacher-researcher was enthusiastic about teaching and inspired enthusiasm in the learners to learn, as was reported by the classroom teacher in both interviews and in the learners' questionnaires, and was also confirmed by the video material. According to Feuerstein and Feuerstein (1991:17), these are important in terms of Reciprocity and Intentionality. The evidence for better mediation started to accumulate and at the end of the second cycle of inquiry the classroom teacher suggested that it was the mediational aspects that made the second cycle of inquiry so successful. In his words:

> [*B*]*ut an overall general feeling about the way you went about it this year compared to last year, is to say that* [pause]*... Somehow I get the feeling and maybe your results will show that we were more successful with this group, despite them being younger. What comes into mind straight away is the mediating aspect from your teaching side of things*. (Interview script, 2003:1)
>
> *Compare it to last year, there is a significant difference in my opinion. I have no doubts in my mind that the mediation in general and across the 16–17 lessons done was a great improvement on the last year. And that when we had our feedback sessions after the lessons — the few little improvements that we wanted to make would be carried forward into the following lessons.* (Interview script, 2003:8)

Another manifestation of successful mediation is an increase in the frequency and quality of the critical dialogues held in the classroom, mainly evident with the Grade 5 learners in the second cycle of inquiry. What might have influenced the improvement in mediation was professional support, peer reflection through collaboration, and personal motivation to change and improve. These bring about better practice with respect to the mediational aspect, which in turn can affect and enhance success in learners' acquisition of process skills and content knowledge.

Special needs

The third aim of this project was to choose activities which integrate thinking skills and present content in such a way that will be suitable for the learners' needs, and allow them to develop and progress in spite of the problems and difficulties they manifest, such as distractibility, a passive approach to learning, ineffective learning and memory, poor self-concept, impulsive behaviour and low motivation to succeed at academic tasks, which are common among learners with special needs (Ormrod, 1995:193-194). For this purpose we chose IE instruments, which are designed to deal with these kinds of problems. The teacher-researcher integrated exercises into the lessons she designed in such a way that the activities were very diverse and engaging, leading to greater co-operation and anticipation on the part of the learners. Many of the learners remembered even the smallest detail they have learnt from lesson to lesson and they were able to apply the thinking skills sometimes weeks after being taught, and throughout the term. The classroom teacher reported great engagement of the learners in science classroom, there was an acquisition/acquiring of knowledge, usage of thinking skills and processes and according to him the programme was suitable for the learners:

> *I think that has happened because of the way you went about it, the way that you structured the lesson, whether they were allowed to get hands-on experience and use the experiments to arrive at the conclusions that you have seen*. (Interview script, 2002:3)
>
> *Then you have children with writing difficulties/problems, I found the lesson sheets/notes weren't too lengthy, too cumber-*

some in terms of their ability to do the work — in other words, there wasn't much on a worksheet that would overpower (them by saying) — *'I cannot do this ...', feel traumatized by a mass of stuff. It was sufficiently scanty to keep them focused. Because remember, our biggest problem here is focus and throughout we saw that the children, once they got involved individually or in their groups, were able to maintain the focus which is a major thing for us here. If you can hold the kid's attention for 3 to 4 to 5 minutes, you have achieved enormously ... In this instance, the video material will show you, the animated way they got involved and they did their work sheets and surely enjoyed it. So it was very pleasing for me to see that children with reading and spelling problems getting involved with a given worksheet*. (Interview script, 2002:5)

Conclusion

In this article we present the findings of two cycles of inquiry aimed to teach learners with special needs some thinking skills and improve their use in science. There was an improved use of thinking skills, increase of critical discussions, and use of metacognitive abilities as well as acquisition of content knowledge. These findings suggest that the approach to teaching thinking skills and processes and bridging them to the science learning area explicitly enabled the learners to cope well and that it is therefore suitable for learners with special needs. In South Africa, where the education system is shifting to one that is more inclusive the explicit of teaching of thinking skills in all classrooms will be crucial.

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Nilly Galyam completed her PhD at Stellenbosch University in 2004. After completing her degree she returned to Israel and will take up a teaching post in Special Education at the Tel Hai Academic College. Her primary interest is improvement of thinking skills in science in learners with intellectual disabilities.

Lesley Le Grange holds a personal Chair in the Department of Curriculum Studies at Stellenbosch University. He teaches and researches in the fields of environmental education, science education and research methodologies. He has more than 90 publications to his credit.