The Use of Investigative Methods in Teaching and Learning Primary Mathematics in the Northern Province Schools (South Africa): A Case Study

Mokgoko Sebela
Northern Province Education Department Advisory Services, South Africa
<mokgoks@iafrica.com>

Research was conducted in the Northern Province Primary Mathematics Projects schools. In view of the high failure rate among matriculation students, the researcher believed that it was necessary that ways to improve mathematics understanding should be devised from the foundation level of schooling. He further believed that children learn better in a cooperative non-threatening classroom environment where they are free to participate. Research was conducted to evaluate the use of constructivist and investigative teaching and learning methods as employed by teachers in a number of primary schools in an area in one province in South Africa, the poorly performed Northern Province. A pilot study was conducted with two experimental schools and two control schools. The experimental schools were operating under the PMP (Primary Mathematics Project) and were supported by expert key teachers who attended courses at Leeds University in England while others were trained locally in South Africa. The methods employed to conduct the research were both qualitative and quantitative, embracing questionnaires done by 174 teachers, interviews with 55 people, written tests by 350 pupils and observations in classes. The results revealed that student performance in the experimental schools where a constructivist and investigative approach was used was better than the control schools. They indicate that children from PMP schools developed a better understanding of mathematics.

Background

Mathematics is a subject that is regarded as a prerequisite for many careers. Because of its status every child must study this subject up to grade 9 or grade 10 level in South Africa. The methods used in teaching should equip the child with the skills to cope with any relevant numerical or mathematical situation outside the classroom. Our traditional ways of teaching place the teacher in a pivotal position in teaching, with the underlying assumption that the child is an empty vessel. The methods of teaching are teacher-centred, with a teacher acting in a way that serves to 'fill up' the students' empty minds. Traditionally, children are not encouraged to question the teacher. Their only participation is perhaps writing down what the teacher tells them to do. Yet even after such 'expert' guidance by the teacher, children are failing. Mathematics performance and results in schools remain poor, while the skills acquired in the classroom do not seem readily transferable.

The theories of educationists like Haire et al (1978) and Howe (1988) suggest that children learn better when they are actively engaged in learning mathematics. How 'active' should this engagement be? At the very best, it should involve pupils talking together about what they are trying to learn, the theory being that meaning is negotiated through discussion (Sebela, 1990). Piaget (1970) and Skemp (1979) have written about a constructivist model for learning. They suggest that knowledge is not transferred ready-made to children, but that children are active participants who construct their own meaning to form new ideas from their own understanding.

A project had been initiated in the Northern Province to address the problem of students failing in mathematics. The underlying rationale of this project is the constructivist postulate that children learn mathematics from their own experiences, out of which they build meaning for themselves. They assemble their own knowledge that arises from a range of problem solving experiences, and through collaborating in discussions they make mathematical sense of it (Ernest 1989, Lakatos 1976). What has become known as the investigative approach is being used to see whether it can alleviate the problem our teachers and pupils are experiencing. The purpose of the study was to find ways of helping parents, teachers, lecturers and pupils/students to develop a positive attitude towards mathematics. Some of the research questions that were to be investigated:

Were the children who are taught through investigative teaching able to develop better understanding of mathematics than those who were taught through the traditional methods where they only listen and react to the teacher's instructions?

Did the attitudes of parents, teachers and lecturers in areas where the investigative approach was used change?

Were the teachers inspired to use group work in their lessons?

Were the teachers encouraged to use discussion and investigation during their mathematics lessons?

The Setting

Constructivist Theory, Cooperative Learning and Investigative Teaching as Followed by Teachers in the Project Schools

Two experimental and two control schools were involved in the study. In the experimental schools teachers were encouraged to change their traditional teaching to incorporate constructivist methods, using ideas such as those of Suggate (1995) and Hoines (1974). Teachers were guided to do the following as constructivist practitioners:

- Not to preach or dictate to the children about what they wanted them to know, and to change their role from that of teller or authority. To change their role from that of teller or authority of all the knowledge children should know or should not know.
- To use problem-centred approaches to teaching, basing their teaching on tasks or problems to which children can relate, to give children opportunity to construct their own mathematical understanding.
- To encourage children to create new mathematical knowledge by reflecting on their physical and mental actions. To make what they learn or acquire meaningful by integrating it into their existing structure of knowledge.

Learning is a social process in which children grow into the intellectual life of those who are around them (Bruner, 1986). A mathematics classroom should be seen as having a culture where children are involved in negotiation, explanation, evaluation and the sharing of ideas. Olivier (1989) also supports the idea that students are not supposed to be seen as passive receivers of knowledge.

Students learning through constructivist approaches are seen to be autonomous and self-motivated, and they in turn acquire the understanding that they do not acquire mathematics knowledge from their teacher but from their own explorations, thinking and participation in discussions. The role of the constructivist teacher is to guide and support the student's

invention of viable mathematical ideas rather than to transmit "the correct" adult ways of doing mathematics (Clements & Battista, 1990, p. 35). Teachers using this method must be able to provide taks and opportunities for dialogue that bring about appropriate conceptual reorganisation in the pupils. Mason (1989) emphasises the same idea by indicating that pupils make sense of the world by assembling fragments of their experiences into some sort of story. This is again stressed by Gadanidis (1994) that

> ...students acquire new knowledge through an active process of assimilation and accommodation, where new as well as existing knowledge is transformed as students construct more inclusive schema of understanding. This theory contrasts the view that students acquire new knowledge through a passive process of transmission, where knowledge is passed unchanged from teacher to student. Even in learning situations that are considered passive, such as a lecture, students construct their own understanding. In the constructivist view of mathematics learning, the question is not whether students construct understanding of mathematics concepts but rather how good are their constructions. Thus, a constructivist teacher's emphasis is on creating learning environments that help students create good schema of mathematics understanding. (p. 93)

In this approach pupils are encouraged to exchange points of view rather than accept an imposed idea of correct and incorrect methods. They are seen essentially as scientists who constantly test out hypotheses about the world in which they are living as social beings (Piaget, 1970).

An important aspect of reconstructing education in South Africa is the transformation of classroom practices to include approaches to learning and teaching that are "learner-centred and non-authoritarian and encourage the active participation of students in the learning process" (ANC, 1994, p.69). Presently group work is beginning to appear in our classes. Group work and co-operative learning are essential in constructivist teaching and learning. Cooperative learning is thought to work well in mathematics because it pulls pupils of differing abilities together. Pupils of different backgrounds are placed in situations where they can all participate equally in learning. In his discussion of peer group cooperative learning, Brodie (1995) suggested that peer groups tend to provide more equality in interaction and to allow pupils more control over the learning situation and the knowledge developed. A report by Lilford (1995) supports cooperative learning by quoting from the Bible: "two are better than one, because they have a good reward for their toils. For if they fall, one will lift up his fellow, but woe to him who is alone when he falls and has not another to lift him up" (p.124). Lilford quotes a grade 11 girl, Jennifer Holem, who says: "Working together and having the chance to give your opinion boosts your confidence and encouraged you to work ever harder. My marks went up by five percent." (p. 126) The five essential elements of cooperative learning as suggested by Oberholtzer (1992) are as follows: positive interdependence, face-to-face interaction, individual accountability, interpersonal social skills, and analysis of how the groups work.

In groups, pupils are dependent on one another. The interaction is a verbal exchange among them. They are themselves responsible for learning to use the material. Children learn to work together with other people just as they need to in life as a whole. They are also developing their social responsibility. Davidson and Maher et al (1990) have argued further that small groups provide a social support mechanism for the learning of mathematics, while Brombacher (1995) states that the notion of cooperative learning comprises more than just group work. This is understood to mean that group work is where individuals are working with a particular person dominating, that is, where only one member is accountable and the rest are depending on him/her. Cooperative learning means that all group members are

accountable and they reach agreement through mutual argument and consensus while learning from one another. In cooperative learning each member is used as resource.

The investigative teaching approach requires the teacher to have confidence in him/herself and be flexible in his/her approach. Pupils are given the freedom to interrupt the teacher. This approach (investigative) discourages teachers from being simple imparters of knowledge (Lerman, 1983). Instead they become facilitators of the pupils' activities, so as to allow learners to construct meaningful mathematical knowledge for themselves (Ernest 1989; Lakatos, 1976). The approach opens room for back stage participation that allows the children to talk and debate; the teacher stands aside and becomes the observer of what the children are doing, children are more actively involved than the teacher, whose role is nevertheless to facilitate the participation within the groups. Tonkin (1995) supports the idea that discussion between pupils is essential in the learning of mathematics, and suggests that investigations provide ideal opportunities to promote group work and interaction between pupils.

In the study teachers were encouraged to adopt James' (1992) model of investigations which proposes steps:

- The Do and Talk model - where learners do practical activities and the teacher feeds in the necessary language.
- Towards Recording model - children write down what they have been discussing.
- Practice and Consolidation - they use the textbooks to practice what they have learnt to perfection.

Learners from the experimental schools were trained on problem-solving strategies used by different educationists like Polya and Simmons. Polya's (1945) strategies are: draw a diagram, examine the special cases, introduce notations to, and noticing quantities that increase or decrease together. Simmons' (1993) problem-solving process includes the following steps: situation, problem, mathematical problem, using mathematical knowledge, techniques and insight, and the solutions.

Teachers from the experimental schools were encouraged to be facilitators in their classes and to play the following roles:

- encouraging personal responses, introducing controversy, summing-up and generalising,
- tolerating noise or silence, clarifying, informing and supporting,

Key Teachers' Roles

Key Teachers support the schools in their ways of introducing the new approaches to teaching. Some of these people were college lecturers from different regions in Northern Province.

Methodology

Both quantitative and qualitative methods of research were used in this study. Observations of classes and interviews with learners and parents were used. As well, questionnaires were given to teachers.

Teachers' Questionnaires and their Structure

A questionnaire was given to teachers from both project schools and the control schools in order to establish a sound comparative basis. It was comprised of a group of sixteen multiple-choice questions, followed by a second group of five that required detailed responses.

The multiple-choice questions were to be answered on a five point scale ranging from 1 (I disagree strongly) to 5 (I agree strongly). The 16 questions were grouped into four subject areas, each with four questions. The four subject areas were Standards, Support, Teaching Approach, and Attitudes. Examples of the questions may be found in Figure 1.

Section A: Standard

3. The mathematics results in my class are better than in the previous years. 1 2 3 4 5

Section B: Support

5. I am supported by my principal. 1 2 3 4 5

Section C: Teaching approach

12. The investigative approach work as well for weak students as for bright students. 1 2 3 4 5

Section D: Attitudes

15. The students like to work in groups. 1 2 3 4 5

Section E: (Detailed Responses)

17. What do you consider as a major area of need within the Mathematics Education at your school?

.....

.....

18. What sort of things do you do in class when you use the investigative approach?

.....

.....

1. What do you like about the new approach?

.....

.....

Figure 1. Examples of questionnaire items.

The objectives of designing the questionnaire items were:

- To check whether teachers have sufficient support from their colleagues and the principals for the approach to be used in their classes.
- To find out whether investigative teaching and learning has really changed the pupils' attitudes to mathematics learning.
- To identify problems that occur when the approach is employed in the classroom in mathematics lessons.
- To find out what teachers like or dislike about the new approach to teaching.

Children's Test Writing in Mathematics

Tests were given to the learners as a way of finding out whether the methods used can really help children to pass their examinations. A pre-test and a post-test were given to both

experimental schools and control schools. The tests were written by grade 2, grade 3 and grade 4 students. The nature of the tests was planned in such a way that students can use any method they have been trained with before. They were to use their own methods or the prescriptive methods given by their teachers.

Results

Reflections Made by the Teachers on their Work in the Different Schools

- Children must be given chance to express and formulate word problems from their environment using concrete objects.
- Colour should be used because it can help to understand the concept "set", but it should be realised that colour should not interfere with addition of concrete objects.
- Children should be allowed to write what they say.
- A student when giving a report should be positioned so s/he is visible to all the class.
- The teacher must take care with individual learners dominating the classroom discussion.

Test Results

In all cases the results favoured the experimental schools irrespective of class size. These tests convinced the researcher that children taught through investigative teaching and cooperative learning methods performed better than the children who are taught using traditional methods. Constructivist and cooperative learning with investigations are the methods that could be used in our schools.

Summary of the Responses

1. The test results: These indicate that the investigative approach produces results so superior that the approach is to be recommended in all schools in the province.
2. Principals, teachers, advisers and inspectors' interviews: They recommend that in-service training courses be organised to train teachers on how to implement the constructivist approach and how to control and deal with pupils learning through group work.
3. Teachers' questionnaire: Overall, responses to the questionnaire evinced a positive feeling that the standard of mathematics teaching, the teaching approaches, the support for mathematics and the attitude towards mathematics have all changed for the better since the implementation of the new approach.

Primary children are said to be influenced by the teacher's motivation and love for the subject. From this research we are led to believe that children love mathematics. Can't this love be extended upward into the next levels of schooling? What remains a source of surprise and concern is the children's failure when they go on to secondary schools.

Conclusions

The Research Findings

- Children who are taught through investigative teaching methods are achieving higher test scores than children who are taught through the use of traditional methods.
- Most of the teachers who have been exposed to the approach in courses or through literature are in favour of it. These teachers are inspired to use group work. They recommended its implementation in all schools in the province.

Implications for Mathematics Education

- The research findings indicate that many changes need to be effected in mathematics education. Teaching styles and methods need to be reviewed. Colleges of Education also need to change their pre-service and in-service training methods with respect to mathematics teaching and learning.
- Management in schools and classrooms needs to be studied. Principals and teachers should be encouraged to do research on how to manage the changing classroom situation, and also on how to manage the school as a whole, in conjunction with community involvement.
- The curriculum should be changed to allow room for the use of investigative methods.

Limiting Factors of the Study

- Lack of literature on science and mathematics education in local libraries.
- School boycotts caused the researcher to have difficulty in visiting the schools to collect data. (i.e., on some days there were no children nor teachers in schools).

Recommendations

- Schools should be structured so as to reduce the number of children in each class to be a manageable number; that is, primary schools less than 40; and secondary schools a maximum of 30.
- More in-service training courses be provided for all mathematics teachers at the beginning of the year, with follow-up courses each quarter. Such follow-up courses could be organised for each district.
- Teachers who attend in-service training courses be given support by key teachers to help them implement what they have learned at the courses.
- Seeing that the primary school children enjoy learning through the use of learning aids, it is strongly recommended that teachers should be trained on how to produce their own materials and equipment.
- Children in a mathematics learning situation should not only be seated in a way that they all face the chalkboard; they should rather sit in a way conducive to conversation or dialogue without interruption.
- Expert mathematics teachers should not be obliged to change subjects frequently (in some schools principals are allocating new subjects to teachers every year).
- Provincial libraries should be equipped with books on mathematics education.
- School-based INSET (In-service Training) should be supported and implemented in the different schools and districts as this will empower the teachers.

Some further research questions identified by the researcher were

- There is a need to conduct research on the effect of interviews and dialogue in mathematics teaching and learning.
- Long-term research should be done to find whether the attitudes of parents, the community and students towards mathematics is improving, and to look for strategies for developing positive attitudes.

The results of this research are being communicated with the department of education such that implementation of constructivist methods can proceed in all schools in the province. This is being reinforced by Curriculum 2005 that demands teachers to change their chalk-and-talk methods of teaching.

References

ANC. (1994). *A policy framework for education and training* (Discussion document). Johannesburg: Braaamfontein.

Brodie, K. (1995). *Small group work; teaching and learning.* Paper presented at the 16th National Convention on Mathematics and Natural Sciences, Johannesburg.

Brombacher, A. (1995). *Application of cooperative learning in the mathematics classroom.* Paper presented at the 16th National Convention on Mathematics and Natural Sciences, Johannesburg.

Bruner, J.S. (1986): *Actual minds, possible worlds*: Cambridge, Mass: Harvard University.

Clements, D.H. & Battista, M. T. (1990). Constructivist learning and teaching. *Arithmetic Teacher*, 34-35.

Davidson, B. R. & Maher, et al (1990). *Constructivist views on the teaching and learning of mathematics*. Reston, VA: NCTM.

Ernest, P. (1989). *Mathematics teaching. The state of the art.* London: The Falmer Press.

Gadanadis, G. (1994). Deconstructing constructivism. *Mathematics Teacher, 87*(2).

Haire, A. et al (1978). *Discussion as a teaching strategy.* Coloraine: New University of Ulster Education Centre.

Howe, A. (1988). *Expanding horizons: Teaching and learning through whole class discussion.* Exeter: Short Run Press.

James, C. N. (1992). Investigative approaches to the learning and teaching of mathematics. In *Mathematics education for in-service and pre-service teachers*. Pietermaritzburg: Shuter and Shooter.

Kamii, C. (1990). Constructivist and Beginning Arithmetic (K-2). In *Teaching and learning mathematics in the 1990s*. Reston, VA: NCTM.

Lakatos, L. (1976). *Proofs and refutations.* Cambridge University Press.

Lerman, M. (1983). *Degrees of unsolvability: local and global theory.* New York: Spriger Verlag.

Lilford, D.I. (1995). Co-operative kids. (A report on co-operative learning). *Fair Lady, 5*, 125-126.

Mason, J. (1989). Geometry: what, why, where and how? *Mathematics Teaching, 129*, 40–47.

Oliver, A.J. (1989). Handling pupils' misconceptions. *Pythagoras 21*, 10-18.

Piaget, J. (1970). *Genetic epistemology.* New York: Columbia University Press.

Polya, G. (1945). How to solve it? New Jersey: Princeton Press.

Sebela, M.P. (1990). *Discussion in mathematics lessons.* Unpublished doctoral dissertation, University of Birmingham, England.

Simmons, M. (1993). *The effective survey sampling.* Massachusetts: Duxbury Press.

Skemp, R. R. (1979). *Intelligence, learning and action.* New York: Wiley.

Suggate, J. (1995). Children's informal methods of addition and subtraction. *Mathematics in Schools*, 43-45.

Tonkin, R. (1995). Investigations in primary school mathematics. *Pythagoras 36*, 29-30.