
4-Kubers in Africa

R. van Niekerk

Educational Research Group for Spatial
Orientation and Spatial Insight (SOSI)

Department of Didactics, University of South Africa

1 introduction

Very little research has been done in the South African situation with respect to the spatial knowledge of children in primary school viewed against the background of a problem-centred approach to mathematics teaching and learning (Booyesen 1994, p.10). In order to clarify this situation research is needed to be conducted to establish the level of spatial competence of the South African child. It was therefore necessary to establish which skills (or lack of it) children needed to adequately solve problems of a spatial nature.

The Dutch unit, called '4-Kubers' (Wijdeveld, 1977) was chosen as pilot material for mainly two reasons:

- mathematical

The following mathematical objectives were part of the unit namely, working systematically, finding descriptions for spatial phenomena, investigating the similarity of objects and movement between two-and-three dimensions;

- didactical

Apart from a spatially well-developed unit with a hierarchy of development the teaching unit was accompanied by three different perspectives namely notes from the researcher, notes from the teacher as well as notes from the children who took part in the activities. This empowers any prospective reader or teacher with sufficient information to differentiate between their own special settings.

From existing literature it has become clear that a major paradigmatic shift has to be made concerning the research approach needed to answer current research questions regarding the teaching and learning of mathematics. According to Schoenfeld (1994, p.708) the reason for this was on the one hand the limitations of the established methods and perspectives on teaching and learning and on the other hand the opening of new avenues.

During a research method, where the major question is to describe the conditions under which learning takes place, the focal point is not on the improvement of the learning/teaching situation per se but on the 'how' of the situation. According to Gravemeijer (1994, p.450) during developmental research knowledge gain is the main concern and the focus is on building theory thus explicating implicit theories. He states that at the onset the theory consists of a global framework which eventually concretises into local theories. It was the objective in this project to use the '4-Kubers' version as the 'global theory' and to develop it into a 'local theory' after completion of the project.

2 theoretical perspectives

Three very important issues were kept in mind during the planning of this project, namely the specific teaching philosophy that is needed to develop the spatial skills of children, the influence of the worldview and culture of the different groups of children, and describing and developing a specific set of skills involved in developing the spatial competence of young children.

teaching philosophy

From the outset it was the intention of the researcher to create conditions through the utilisation of materials and the activities which would foster the children's own understanding and own creations. The role of the teacher had to be one of a facilitator and the children had to be allowed to negotiate their understanding of the materials in a free and easy way with each other and also with the teacher. This implies that the teachers of these children had to understand this approach and had to allow this way of learning in their classrooms. The children were put into groups and the majority of the activities were conducted while the children were free to negotiate with their peers in the group. Negotiations about the different spatial issues between different groups were also encouraged.

worldview and culture

The researcher was profoundly aware of the fact that in the case of the black children there might have been a totally different worldview which influenced and directed the way in which they viewed the world around them. On a day to day basis, to most people in a Western culture, Euclidean spatial concepts prevail. This situation is clearly mirrored in the geometry curricula of schools in Western countries.

In their research among the Navajo people of America, Pinxten, Van Dooren and Harvey (1983, p.156) concluded that the widespread ineffectiveness of schooling amongst those people may range from social and cultural factors to the fundamental and poorly understood lack of commensurability between Western and Navajo knowledge systems.

The success of Piagetian approaches in education within the school system can at least be partly explained by the fact that, for example in geometry, these are founded on and built up from logically satisfying and closely similar or naturally presupposed pre-school notions. In other words pre-school knowledge is highly appropriate to and compatible with the contents of the instruction in the formal school setting. Western culture has been built on a spatial systematisation which has clearly continuous and smoothly developing stages which stretches from the natural environment and its conceptualisation all the way to more abstract and complex geometries. This seeming relativisation of Piagetian notions is not new and this critique on the Western biases in Piaget's theory of intellectual development has been voiced by several authors (Pinxten et al., 1983, p.157).

The difference between the Western way of thinking about space and the Navajo (non-Western) way can be summarised under three main points namely a specific hierarchy in spatial structuring, a part/whole distinction and the static/dynamic worldview (Pinxten et al., 1983, p.157-160):

the specific hierarchy in spatial structuring

In his explanation of the construction of space Piaget (along with others like Bruner, Furth, and Goodnow) gives a detailed explanation of the way in which more sophisticated notions are linearly deduced, or construed in a systematic one-to-one progression, from notions acquired earlier. According to him the notion of 'distinctness' is built upon that of 'neighbourhood'. The notion of 'order' is again built upon the combination of both "distinctness" and 'neighbourhood' and 'border' is again built upon 'order' and so forth. Thus more sophisticated notions (the projective and Euclidean ones) are integrated into the total concept, which on completion will eventually consist of a number of linear and systematic progressing procedures.

Curricula can take these for granted (in a specific order of acquisition) and construe the logically and genetically 'subsequent' notions quite naturally on top of and on the basis of these topological notions. The Navajo space concept appears to be quite different. They propose to have three equally important basic notions (movement, volumeness/planeness, and dimensions). All three are topological in character and none of them are 'primitive' in the same sense as the Piagetian and Western notions.

the part/whole distinction

A certain atomism is characteristic of the current Western style of thought. The 'objectification of the environment' is taken for granted in the sciences for example situations and static entities which can be abstracted from their environment for a certain time, and in school instruction where we study particular animals, places, and objects in themselves. A particularly powerful aspect of this approach, is the segmentability of objects, and space and time as aspects of objects. Consequently one should emphasize that, in order to successfully approach or learn the more systematic presentation of Western knowledge, as this is attempted in the school setting, a clear and common understanding of 'part/whole' notions is an absolute prerequisite.

The 'part/whole' distinctions that proved so important in Western thinking and knowledge systems play a minor role in Navajo knowledge. Navajos tend to speak of the world in terms of processes, events and fluxes, rather than parts and wholes or clearly distinguishable static entities. The emphasis is on continuous change rather than on atomistic structure.

the static/dynamic world

According to the Western school of thought the outside world is primarily interpreted as a composition of situations, objects and transitions between situations and not as a composite of processes and actions. Pinxten et al. (1983, p.159) emphasizes that in the Western schooling (and Western knowledge for that matter) the world is looked at first and foremost in terms of objects, states, situations and constant aspects of phenomena and the dynamic aspects are introduced in a lesser and at least secondary way. The Navajo world view stresses the dynamic rather than the static aspects of reality. Other aspects of time (the notions of 'generation' and 'linear progression of time') are held as separate and 'genuinely temporal' features and consequently one can speak of 'time-space' in the Navajo world view referring to the relatively 'time laden' identity of space. In other words, spatial phenomena always have this special dynamic aspect, which from a Western point of view makes them different and less strictly or purely 'spatial' than for example Euclidean geometrical notions.

Very little research has been done in the South African context to clarify the above three-mentioned issues concerning the way in which all the peoples of South Africa view the space around them. There are indications though from anthropological literature that a strong possibility exists that many of the black cultures in South Africa do not view the space around them in the standard Western way (Bruwer, 1956; Mönning, 1967 and Walton, 1956).

subject specific issues

From the subject point of view it was important to clarify the different skills and levels of competence in the skills displayed by the different groups of South African children. Research done by Van Niekerk (in press, p.253) found that spatial activities, conducted in the different executional media (language, drawing/writing and construction), serve to support the development of the different spatial skills. The four different skills that are being focused on in the development of the spatial competence of the children are grouped under four categories namely: visual skills, verbal skills, tactile skills and mental skills. The development and description of these skills, and their interrelationship with one another when a child works from three-dimensions to two-dimensions and vice versa, are crucial components of any spatial development program for young children.

In the multicultural situation which prevails in South Africa it is very important that the above-mentioned issues are very well researched before any attempt is made at the development and implementation of a prospective spatial/geometry curriculum for the primary school.

3 experimental background

Research was conducted over a period of two years and all the classroom events were video recorded for analysis afterwards. Three different cultural groups, all in their third year of school, took part in the experiment. These children all live in a radius of approximately 30 km from one another. The details of the different groups are presented in figure 1.

group	multicultural	sotho	shangaan
average age	9 years	9 years	11 years
number of children in class	24	48	45
economic status	above average	very poor	very poor

figure 1

The multicultural group consisted of 60 percent white children with English as their first language and 40 percent black children with English as a second or even a third language. Both the black groups, Sotho and Shangaan, are culturally homogenous.

The work with the multicultural group was undertaken first during 1994, and after these materials were developed, they were used as pilot materials for the other two groups which were tested simultaneously during 1995. In all three cases the researcher and the teachers worked very closely together. During the work with the multicultural group both the teacher and the researcher acted as teachers whereas in the case of the Shangaan and the Sotho children only the teachers presented the classes because the researcher could not speak any of the black languages (which is a big handicap in itself).

During the instruction the children in the multicultural classroom were taught in English while the children in the Shangaan and Sotho classes were taught in English and their mother tongue simultaneously. The reason for this is that in the black schools most of the teachers are of the opinion that children should be introduced into the English language as soon as possible but they differ however about the time and the way in which this introduction should take place. This in itself has very serious implications for the implementation of any subject into the classroom of the black child.

4 results and discussion

For the purpose of the discussion the results will be interpreted under the different theoretical issues that were mentioned in section 2.

teaching philosophy

Traditionally young children in the black cultures have a different relationship to their elders and their peers in comparison with the average young white child in South Africa. In many of the different black cultures children are not encouraged to negotiate issues with their elders. Words and views of the elders are accepted without much deliberation (Bruwer, 1956, p.49). In many of these cultures the position of women and girls are also still being viewed as being inferior to men and boys. Both these issues can have a profound influence on the development of a classroom culture which emphasised free negotiations.

The above mentioned cultural aspects were indeed influencing factors in the case of the Shangaan children, who never really established a classroom culture where free negotiation of knowledge took place. This served as a good illustration to the researcher that views and values which prevail outside school cannot be ignored in the design and implementation of a teaching unit. It was less of a problem though with this specific Sotho class, which also illustrated the complexity of the situation in South Africa

namely that people should not be summarily categorised on the grounds of their cultural backgrounds. The situation with the multicultural group was different because the majority of the children come from a background which encourages communication between elders and peers. The 40 percent of the class who came from other cultural backgrounds adopted the classroom culture which was dictated by the majority of the children along with the teacher. In both the Sotho and the multicultural classrooms the teachers were very effective in dealing with their roles as facilitators. This was in sharp contrast to the teacher in the Shangaan classroom. Another very important difference between the multicultural and Sotho teacher on the one hand and the Shangaan teacher on the other hand was the fact that the former two teachers adopted the same teaching style when they taught other subjects as well. The Shangaan teacher only tried to adopt this style when teaching the spatial unit and she diverted back to her former style with the other subjects (transmission of knowledge with no negotiations). This was clearly very confusing for the Shangaan children. It should be mentioned that during their first three years of primary school, children in South Africa are taught all their subjects by one teacher.

Another important factor is the structure of the different black languages. Compared to English not one of these languages are on the same technical level as English. In some of the black languages the use of prepositions as known in the English language are limited or even totally absent. Some of the spatial terms in English do not even have equivalents in some of the black languages. In some of the black languages the same spatial term is used to indicate different actions which can only be distinguished if it is put into context. This situation, which obviously still requires intensive investigation, serves to complicate the matter even further.

Another feature which influences the teaching of black children, is the incompetence of many of the black teachers with the English language! This issue was once again very clearly visible during the development of this unit. One of the ways in which the researcher tried to overcome this problem was to have very intense training sessions with the teachers before and after the classes. This included looking and discussing the video materials that was taken during the previous lessons.

worldview and culture

According to the Dutch version the '4-Kubers' unit is set against the background of a story involving the activities of 'Paulus Poskabouter' and his miniature friends, and their inventions of different four-cubed houses. On implementing the unit, the researcher had to make the first change by

choosing another context. Traditionally the black child in Africa associates a character of diminutive size, as hinted by the Dutch version, as being a bad or mischievous spirit. In African folklore this character is even called by a specific name 'Thikoloshe' (Bruwer, 1963, p.150). For the purpose of the research the unit was renamed, 'Pre-fabricated Houses'. This allowed the researcher to use a very topical issue in South Africa namely the shortage of houses as a suitable context.

There were also other hitches though because later in the Dutch version, when the different houses were designed, the children made use of the idea of a second and a third housing level. The majority of the rural black children in South Africa have never seen such a structure. The multicultural group though had no problem with this, because there were many examples of this building type in the areas they came from.

Another problem that was induced by the use of a real world house in the South African situation, was the introduction of a scale change. In the case of the Dutch version, the children worked with small people who could easily fit into houses built with blocks. In the case of the South African child, the pre-fabricated house idea, which is an actual house in which big people live, were copied and manipulated by making use of play blocks. Even though the researcher was able to adjust the context to a large extent, this scale jump was a factor which might have complicated the matter. In order to compensate for this problem the children were requested to design scale models of these houses with cardboard.

This also allowed for the much needed physical manipulation of materials to which the average black child has little access because of their financial situation.

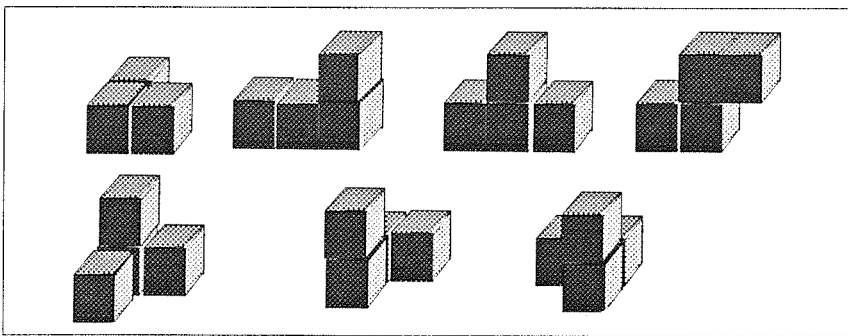


figure 2

subject specific issues

The fact that all the black children were being taught in a mixture of their own language and English, forced the researcher to design a series of pre-

activities in order to clarify and establish the children's use and knowledge of the basic spatial terms related to direction namely, left, right, on top, behind, in front, at the back of, next to, etcetera.

For the purpose of these activities use were made of soma cubes (compare figure 2).

The type of activities that were conducted to develop the use of these different spatial terms are illustrated in figure 3.

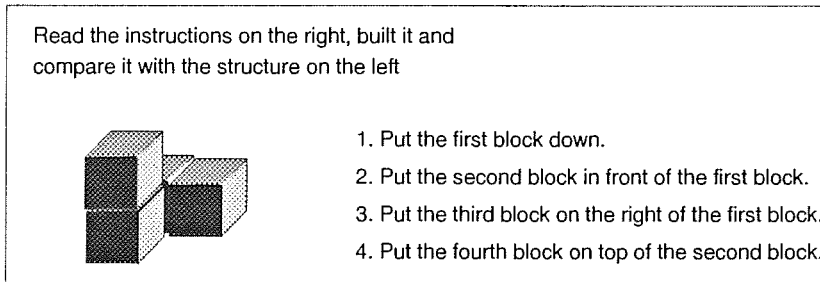


figure 3

It was found that many of the black children not only had problems with left and right linguistically, but also conceptually. This was not the case with the multicultural group who come from an upper-class highly skilled community. Many of the black children also had difficulties moving from two-dimensions to three-dimensions when completing a workchart, as illustrated in figure 4.

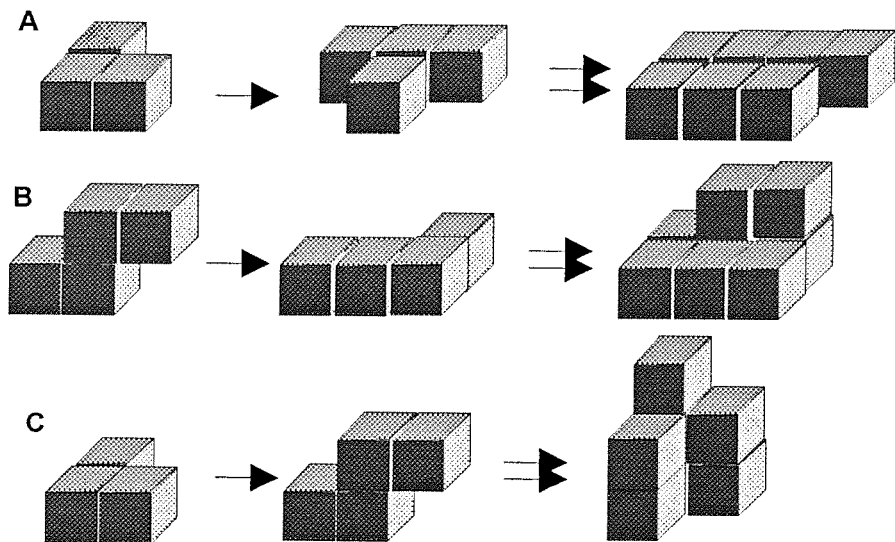


figure 4

Quite a number of these workcharts were introduced where the children were given these 'pictorial manuals' and they had to then physically manipulate the soma cubes and through 'reading' the manual build the structures. In other words they had to take the two soma pieces that are joined by the single arrow and manipulate it in such a way that the structure which follows the double arrow is found.

Care was taken to introduce activities of this nature which allowed for rotation along all three axes (x , y and z) in order to ensure that not only the easier rotation situations were presented but also the more difficult ones (compare figure 5 which shows the different rotations along the axes).

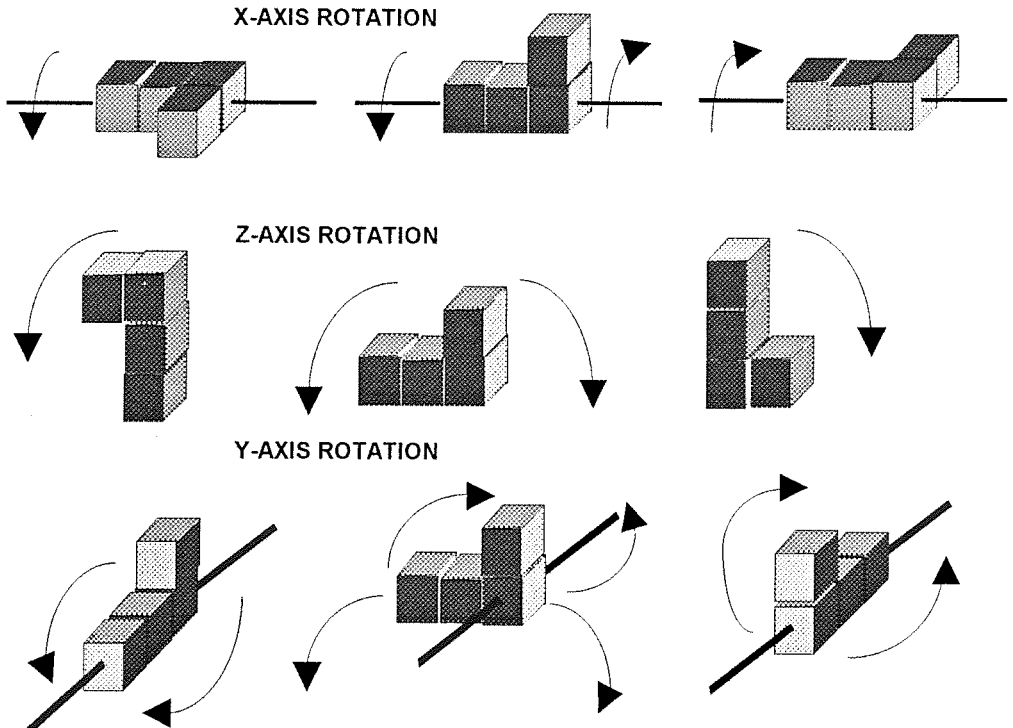


figure 5

It is known from the literature that children find rotations along the x - and z -axes easier than those along the y -axis (Olson & Bialystok, 1983, p.150). Most of the children who took part in this experiment found the structures in figure 4A easier to build than in figure 4C.

One of the reasons for the above mentioned situations might be the fact

that most of the black children have little or no access to books (apart from their school books) because of their socio-economic situation (many of their parents are illiterate).

All the children (all three groups) who took part in the experiment, experienced difficulty with the movement from the three-dimensional representations of the structures (soma cubes or 4-Kubers) to the grids ('plattegrond').

An interesting level-difference discovered during this work and which was not mentioned in the Dutch version, is the fact that if the children were presented with pictures of the structures which they had to convert onto the grids, then the weaker children first had to reconstruct it with physical materials before they could fill in the grids (compare figure 6). The cleverer children found no need for the reconstruction of the physical structures and they mastered the grids without the reconstruction phase.

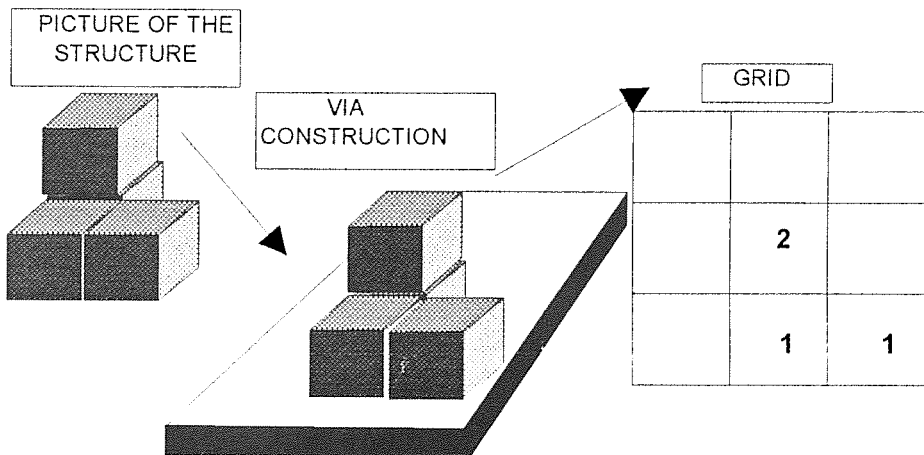


figure 6

The use of grids and graphs and the reading of tables is not a part of the everyday life of the average South African child. In that sense the Dutch society could be described as quite uniform in that all the children have at least seen a bus route being presented in the form of a map, or the time schedules for busses and trains presented in a table form.

South Africa has a very diverse society as well as a infrastructure partly because of the size and the geography of the country. The researcher, for example, first rode on a train when she visited Holland in 1993! This difference of worlds between the Dutch child and the African child might be

one of the reasons why the children found the representation of information in a grid-like form far more difficult than the Dutch children.

5 conclusions

On average the children in the multicultural group took longer to work through the different issues in comparison with the Dutch group, and the two black groups took about twice as long as the multicultural group to complete the same tasks. An important difference though is that far more differentiation could be seen in the activities of the South African group in comparison with the Dutch group. The work with the different cultural groups not only awakened the researcher to the importance of realising the total worlds of the children, but also gave very important indications as to the possible in-between developmental levels that children had to progress through, in order to master specific skills. This is something that is of utmost importance not only for the South African situation but also for the Dutch situation.

The three South African groups all went about it in different ways in developing the '4-Kuber' unit. Even though these children did not take the same time in completing the different tasks they all eventually managed to solve the problems. It became clear that in most of the cases the different skills that were needed could be developed through the introduction of the appropriate activities. This implies that a very high responsibility is placed on the ability of the teacher to recognise the shortcomings and to then intervene with the correct follow-up activities. This places a very high emphasis on the quality of the designed materials as well as the initial training of the teachers.

This investigation has once again illustrated the importance of conducting developmental research when dealing with issues as complicated as the development of the spatial skills of young children. It stressed the very important point that even the best designed materials cannot be used 'blindly' when it comes to implementation in the classroom.

Research of this kind could lead to the situation that the systematic extinction of other systems of knowledge, that is currently taking place, is dramatically reduced thus, preventing the situation of ending up with a knowledge pool identical to the Western pool of knowledge. The risk we take on a world-wide scale, and the impoverishment that can be witnessed from this, is frightening. The final views of the researcher can be summarised by the words of Pinxten et al. (1983, p.174):

'... as long as science cannot pretend to have valid answers to all basic questions, it would be foolish to exterminate all other so-called primitive, pre-scientific or otherwise foreign approaches to world questions.'

note

- 1 The average black child in this area does not own the basic construction materials such as a ruler, a pair of scissors, a rubber or cardboard for construction activities.

references

- Booyesen, E. (1994). *Die vakdidaktiese implikasies van die van Hiele-vlakke van denke in meetkunde vir skoolwiskunde in Suid-Afrika*. Pretoria: UNISA. (Proefskrif, D.Ed.).
- Bruwer, F. P. (1956). *Die bantoe van Suid-Afrika*. Stellenbosch: Afrikaanse pers.
- Gravemeijer, K. (1994). Educational development and developmental research in mathematics education. *Journal for research in mathematics education*, 25(5), 43-471.
- Mönning, H. O. (1967). *The Pedi*. Pretoria: J. L. Van Schaik.
- Niekerk, R. van (in press). *A subject didactical analysis of the development of the spatial knowledge of the young child through a problem-centred approach to mathematics teaching and learning*. Potchefstroom: Potchefstroomse Universiteit vir Christelike Hoër Onderwys. (Unpublished M.Ed. dissertation).
- Olson, D. R. & Bialystok, E. (1983). *Spatial cognition: The structure and development of mental representations of spatial relations*. London: Lawrence Erlbaum Associates.
- Pinxten, R., I. van Dooren & F. Harvey (1983). *Anthropology of space: Explorations into the natural philosophy and semantics of the Navajo*. Philadelphia: University of Press.
- Schoenfeld, A. H. (1994). Research and teacher education: In search of common grounds. *Journal for research in mathematics education*, 25(6), 608-636.
- Walton, J. (1956). *African village*. Pretoria: J. L. Van Schaik.
- Wijdeveld, E. (1977). Vierkubers. *Wiskobas-bulletin*, 6(2). Utrecht: IOWO (leerplanpublikatie 5).

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