EXPLORING THE USE OF ACTIVITY THEORY AS A FRAMEWORK FOR THE TEACHING AND LEARNING OF MATHEMATICS

Jayaluxmi Naidoo

University of KwaZulu-Natal: School of Education

The purpose of this article was to explore the use of Activity Theory as a framework for the teaching and learning of mathematics. The final sample of participants comprised of six master teachers. Qualitative data was collected via master teacher questionnaires, observations of selected lessons, field notes of observations, individual interviews with master teachers and focus group interviews with learners. Data was analysed within an interpretive paradigm. Activity Theory was used as a theoretical lens within which to frame the study. The findings suggest that each master teacher modelled their classrooms as individual activity systems and the teaching and learning of mathematics was completed as a dynamic activity. These findings are important for advancing both teacher and curriculum development.

INTRODUCTION

Teachers are on a constant quest for the ideal strategy to advance the teaching and learning of mathematics. In South Africa, what makes this task more daunting is that all learners are required to select mathematics or mathematical literacy in grade 10 and continue with this choice until the end of their schooling career. Furthermore, learners are expected to write a common national examination at the end of their grade 12 year in mathematics or mathematical literacy regardless of glaring inequalities within school milieus across the country.

Although research focusing on pedagogic strategies within classrooms across various contexts has been conducted, there is currently a gap with respect to research focusing on the pedagogic strategies of teachers in South Africa. The question that arises is how do teachers teach for success in their classrooms? Hence the purpose of this paper was to explore the teaching and learning of mathematics within the framework of Activity Theory. Comprehensive lesson observations and video recordings provided important insights in strategies used by master teachers within differing social contexts. Master teachers in this study are expert teachers as identified by the KwaZulu-Natal Department of Education (KZN DoE). They are experienced teachers with the potential to mentor new teachers (Makapela, 2007). Identifying teaching strategies that support the effective and successful teaching of mathematics within differing social milieus could provide valuable insights for curriculum developers as well as teachers.

THE TEACHING AND LEARNING OF MATHEMATICS IN SOUTH AFRICA

The advent of democracy in South Africa brought huge changes especially with respect to education. Education reformers in South Africa are concerned about the comparisons of South African learners with those of other nations, with respect to the apparent inability of South African youth to successfully participate in the mathematical global market place (Howie, 2003; Reddy, 2006).

Schools play a crucial role in preparing learners from different social backgrounds to meet the needs of an unequal society (Atweh, Bleicher, & Cooper, 1995). Knowledge of mathematics is seen as an important asset for the progression of South African society. Similarly, Reddy (2005, p. 125) maintained that “mathematics and science are key areas of knowledge and competence for the development of an individual and the social and economic development of South Africa in a globalising world.”

With the introduction of mathematical literacy, it is a premise of this curriculum that it would prepare learners with the necessary mathematics skills required by individuals to function as critical, democratic citizens in modern society. Mathematical literacy enables learners to become mathematically literate. To be mathematically literate suggests that learners are able to identify, understand and engage in mathematics as well as to make sound judgements about the role that mathematics plays in the real world (Kotze & Strauss, 2006).

THE USE OF VISUAL TOOLS IN SCHOOLS

Visualisation essentially means the ability to form and negotiate a mental image necessary for problem-solving in mathematics. Visual images refer to the representation of the visual appearance of an object, e.g. its shape, colour and size (Van Garderen, 2006). They also play a decisive role in promoting critical thinking (Rezabek, 2008), learning and communication in the mathematics classroom. This is so because visualisation encourages the use of the concrete to conceptualise abstract concepts and ideas (McLoughlin, 1997; Presmeg, 1997; Solano & Presmeg, 1995). Whilst mathematics encompasses many abstract notions, with visualisation, and visual tool use, these abstract notions are made more accessible to the learner.

Teachers often use visual tools unknowingly in class, for example, when they resort to the use of gestures, graphs, shapes, lines and diagrams. A gesture is any physical body movement (Maschietto & Bartolini Bussi, 2009) that assists in a communication function (Sfard, 2009). Learning environments that incorporate visual tools and technology add value to lessons. In these learning environments, learners are able to interact easily with concepts that were once considered abstract.

For example, teachers teaching transformations in geometry may use technology to manoeuvre rotations and reflect images. Learners are then able to see these transformations, allowing them to concretise these once abstract mathematics concepts. Technological tools like the smart board and the calculator enable teachers and learners to display ideas and allow for multiple interpretations. These interpretations may be discussed, interpreted and revised based on feedback from peers (MccLoughlin, 1997).

Additionally in mathematics there are various computer-based packages (e.g. *Geometer's Sketchpad; Cabri Geometry; GeoGebra; GeoProof; Cinderella* and *Graphmatica*. etcetera) available for the teaching and learning of mathematics. By using software programmes like *Geometer's Sketchpad*, the teacher frees up more time to interact with the learners and to ask conceptual, probing questions (Steer, de Vila & Eaton, 2009). This is ideal for occasions when the learner cannot see or understand what the teacher is talking about within a mathematical context. In addition, these tools have the added benefit of allowing learners to discover rules and generalisations for themselves (ibid, 2009).

THEORETICAL FRAMEWORK

Activity plays an important role in mathematics learning and development (Grives & Dale, 2004), however, very little activity of significance is accomplished individually (Jonassen & Rohrer-Murphy, 1999). Activity theory was used as a framework for the study to account for the systems that link mathematics, learning and the differing social milieus. Based on the principles of activity theory, activity and learning are interactive and interdependent (Jonassen, 2002). This theory is based on the assumption that all human actions are mediated by tools and cannot be separated from the social milieu in which action is carried out. Activity theory in this study provides the framework for describing the structure, development and context for the activities that were supported through the use of visual tools. These tools differed based on the context within which each school was located. For example, during the teaching of transformation geometry, one master teacher used the smart board; another master teacher used a stick with different coloured elastic bands and the next master teacher used paper folding and gestures. These diverse tools were used to teach the concept of rotation and reflection within transformation geometry.

In this study, the activity system under the microscope is the act of teaching and learning in mathematics classrooms. The community within the activity system refers to a group of individuals who share a common objective. Hence, learning is not seen as an isolated act. Learning occurs as individuals interact with each other, and these interactions are mediated by tools. Barab, Schatz and Scheckler (2004) proposed that activity theory emphasised the mutual nature of learning and doing, of tool use and community and of content and context. To clarify, as the learning community within each activity system in the study works and solves problems together, they develop a new set of values and notions.

These values and notions may not be appreciated or understood within other communities and in other contexts. Engeström's (1987, 2001), second generation activity theory model was used in this study. To situate the activity theory model within the context of this study, the subject is defined as the master teacher, the instruments are the visual tools that are used to teach mathematics and the object is the development of the mathematics content. The communities in this study are the learners within the mathematics classroom, the teachers, the staff at

each school and the parents within the community. The subject belongs to a community that is governed and mediated by rules and division of labour. Essentially members of the community collaborate with each other to achieve the outcome of the activity system. In this study the outcome of each activity system was the teaching and learning of mathematics. The model that follows (Figure 1) emerged from this study. This model graphically demonstrates how activity theory was used in the teaching and learning of mathematics. The smaller external activity system that is illustrated in the figure varies for each master teacher.

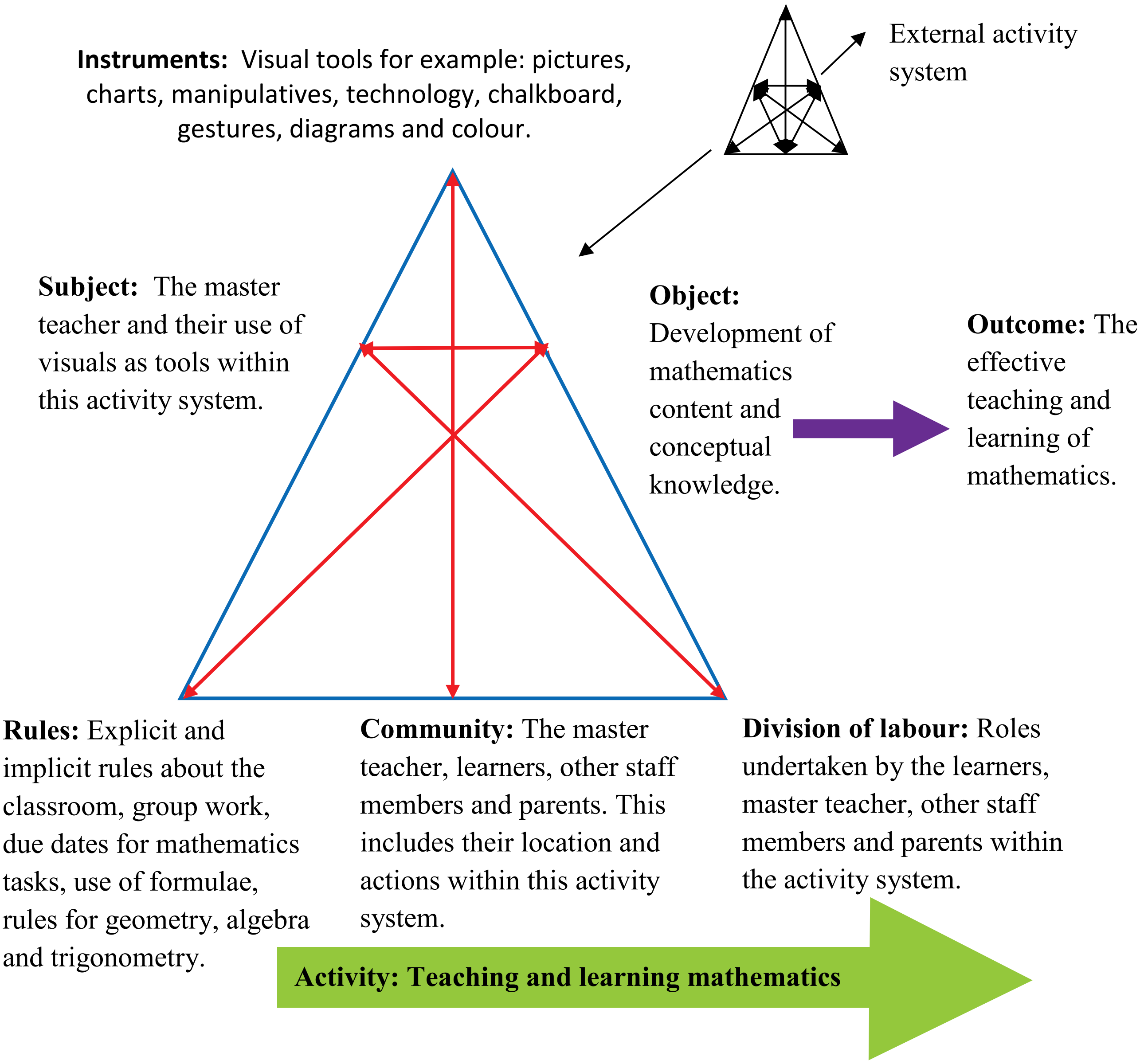

Figure 1: Conceptual model of the human activity system within this study adapted from Engeström (1987, p. 78)

RESEARCH METHODOLOGY

Gatekeeper access was obtained from the KZN DoE first before forty five schools were invited to participate in the study. The schools were selected based on convenience and accessibility for the researcher. Twenty out of 45 schools responded positively to the invite. Ten schools were selected at random to be a part of the pilot study and the remaining ten schools participated in the final study. Based on data collection, analysis and intensive coding, the final sample comprised of six master teachers teaching at six different schools located in KZN. The final sample is depicted in Table 1 that follows.

Number	Master Teacher	School
1.	Alan	Orchard Secondary
2.	Dean	Daisy Secondary
3.	Karyn	Rose Secondary
4.	Maggie	Lily Secondary
5.	Penny	Tulip Secondary
6.	Sam	Carnation Secondary

Table 1 [1]: Participants in the final sample (Adapted from Naidoo, 2012, p. 3)

Learners were selected for focus group interviews at each of the six schools. These learners were purposively selected based on the level of interaction with their teacher and peers in the classroom. The focus group thus comprised of learners who interacted frequently, average and not at all.

Data collection

Prior to the pilot testing of the questionnaire, items on the questionnaire were discussed with colleagues within similar research areas. After minor edits, the questionnaire was pilot tested. Ten of the twenty schools were selected at random to participate in the pilot study. In stage 2 a questionnaire was sent to each of the remaining ten schools. The master teacher questionnaire was a pen and paper questionnaire whereby the master teachers were asked various questions relating to their teaching strategies and resources used. The questionnaire was analysed and coded in preparation for the next stage of data collection. Stage 3 involved the observation and video recording of at least three Grade 11 mathematics lessons that were taught by each of the six master teachers. After analysing and coding the observations, Stage 4 - the master teacher interview phase commenced.

[1] Pseudonyms are used to protect the identity of the schools and teachers.

Each of the six master teachers selected were interviewed using a semi structured interview schedule. Each interview was recorded. Video clips were provided for the master teachers to view. The video clips were selected at critical moments in each of the master teacher's lesson. These critical moments focused on the master teacher's use of visuals as tools in the lesson. The master teachers were asked questions pertaining to their use of the visuals as tools. The master teachers' responses were probed were necessary to ensure that there were no misinterpretations or misunderstandings. After analysing the master teacher interviews, focus group interviews were conducted with learners from each of the six schools. A semi structured focus group interview schedule was used and each focus group interview was recorded. Learners were provided with the opportunity to view the same video clips that were shown to their teachers. Learners were asked questions about the use of these visuals as tools in their classrooms.

FINDINGS AND DISCUSSION

The activity systems

Based on the lesson observations and interviews it was evident that each of the classrooms functioned as an activity system. Each member of the classroom community served a specific purpose and all role players worked in collaboration with the master teacher (subject) to achieve the outcome of the activity. In order for this outcome to be achieved rules were followed and specific instruments were used. The analysis of the six activity systems highlighted different external activity systems that influenced the teaching and learning of mathematics. These external activity systems are discussed below.

The history of poor resourcing:

For decades the history of poor resourcing created disadvantages across schools in South Africa. Sharing of resources causes conflicts with the planning and time management of lessons. For effective teaching and learning to occur it is necessary to make maximum use of teaching time (Pollard & Triggs, 1997). Apart from the sharing of material resources, human resources were also limited. This implied that teachers at these schools spent a great deal of their non-teaching periods serving relief for teachers that were not present at the school. This lack of an adequate support structure, limits the teacher's time for effective planning and preparation for future lessons.

Limited human resources impact negatively on both the community and division of labour within the activity system. Members of the teaching staff within the learning community were burdened by the added pressure of providing adequate support to all learners within the learning community. Teachers were compelled to take on more responsibility and a greater workload. This external activity system led to teachers being overworked, worn-out and stressed in the classroom. This could lead to more teachers being absent than at other advantaged schools.

Moreover, as a result of the limited resources, the master teacher was required to be more resourceful than colleagues at other more advantaged schools. In many cases, the teacher would need to reflect on previous experiences and use a combination of tacit and explicit knowledge in order to be effective in the classroom. For example in Carnation Secondary, the lack of resources caused tension between the visual mediating tools and the master teacher (Sam). Sam reflected on his practice and used manipulatives and visual tools that were easily available to learners within the classroom environment. He used bricks, desks, coloured chalk and mental images to assist his learners. The use of these visual tools influenced the use of instruction time in the classroom. More time was spent in drawing diagrams and mediating tools than in the interaction and engagement within the classroom.

The privileges of a well-resourced school

This activity system at Rose and Lily Secondary School were privileged in all respects when compared to the other activity systems in this study, because these schools had better material and human resources. Teachers at these schools were in abundance, and they were well qualified. This external activity system influenced all aspects of this activity system. The effects on the rules within these activity systems were minimal. Most learners at these schools came from privileged backgrounds and other advantaged primary schools. They were accustomed to the rules of this type of learning environment. The minority of the learners who did not come from privileged backgrounds conformed to what was socially acceptable within the learning environment. They developed a shared understanding with other members of the learning community; this suggested that these learners assumed the dominant practices of this activity system (Naidoo, 2006). The teachers at these schools came from privileged backgrounds and could identify with the learners within these activity systems. The teachers had a range of tools from which to choose and they used their tacit knowledge to make tool use within their activity system beneficial. This dynamic use of tools led to a varied approach to the teaching and learning of mathematics.

With respect to issues of community and division of labour, most of the learners came from better socio-economic backgrounds and hence had the parental support ensuring success at schools. Most parents could afford to provide their children with extra resources to assist with effective learning. These resources included, for example, study guides, computer access, internet access and extra tuition. This extra parental support influenced the roles of the learning community and the division of labour within the classroom. Learners were able to take more responsibility for their own learning. Additionally, being well resourced schools, there was more funds available for employing additional staff members as the need arose.

This relieved the burden of relief teaching and support. Responsibilities could be shared with other staff members and hence more time could be spent on planning and preparing for lessons. What is evident from this discussion is that the external activity system of privilege positively influenced the object and eventual outcome of both Karyn’s and Maggie’s activity system.

The mediating tool of language

The mediating tool of language affected how the rules and instructions were understood within the learning environment. For example at Daisy Secondary, learners came from different language backgrounds and at times these differences created issues of miscommunication within the classroom. The majority of learners at the school spoke English as a second or even third language. Due to differences between the dominant language at home and the language of instruction at school, certain mathematics concepts and rules had to be revisited. This revisiting of mathematics concepts added pressure on the time allocated for syllabus coverage. Regardless of these external conflicts, the syllabus had to be completed in time for the national tests and examinations. To overcome these conflicts, the master teacher (Dean) had to be reflective and resourceful in the classroom.

Within Penny’s activity system, language influenced how she taught the lessons as well as how rules and instructions were interpreted within the classroom context. Language is a cultural matter; it is a way of communicating meanings and of coding events. Generally, children attain a basic mastery of their mother tongue before they start school. Since learners find it difficult to follow instructions in a language that is not their mother tongue, this may account for their poor academic performance (Mwamwenda, 2004). This caused additional conflict and tension within Penny’s activity system. Likewise Zevenbergen (2001a) proposed that the language that learners learn from their homes is prone to locate them more or less favourably at school. This notion is dependent on the correlation between the home and school languages. This suggests that the home and language are connected, with the home being very significant to how the learner communicates within the classroom (Naidoo, 2006).

The links between the school and the home tend to be stronger with families from advantaged backgrounds than with families from disadvantaged backgrounds. Learners from advantaged backgrounds use an “elaborated code” whilst learners from disadvantaged backgrounds use a “restricted code” with respect to language (Bernstein, 1971, p. 76). Learners from advantaged backgrounds have access to both codes and this locates them as having a more dependable voice within the community. Learners from disadvantaged backgrounds may not have access to the elaborated code and this partly explains their underachievement at school (Boaler, 2002).

The personification of characteristics of tastes, disposition and language can be seen to be the structure of habitus. “Habitus” according to Bourdieu is the embodiment of culture and presents the lens through which the world is construed (Zevenbergen, 2001b, p. 202). Each activity system in this study exhibited their own ‘habitus’ whereby each learning community constructed the learning of mathematics diversely. Each learning community in this study used their own symbols and visual tools to make the mathematics more accessible to members within the learning community. Within this activity system, Penny used many differing strategies to compensate for the differing backgrounds of her learners. Penny also used a combination of group work and individual work during her lessons.

Within Sam’s activity system the language used at home caused conflict with the language of instruction. This conflict posed problems for Sam when he tried to engage learners with the mathematics being taught. If one does not have exposure or experience of certain words and concepts, one would not be able to communicate effectively within a classroom context. One would be functioning within Bernstein’s “restricted code” of language (Bernstein, 1971, p. 76). Rules related to the content taught and concepts learnt will most likely be misunderstood. Thus, apart from the use of visual images to assist in making the language of mathematics more comprehensible and accessible, Sam encountered an added dilemma. Sam needed to ensure that the visual tools used would be understandable to all his learners. He needed to ensure a levelling of the mathematics ‘playing field’ before any teaching and learning could occur.

The lack of discipline

The external activity system of lack of discipline affected the rules of the classroom, the learning community and the division of labour within Penny’s activity system. In every classroom there are rules to be followed. This assists in attaining Levels 2 to 4 of Maslow’s hierarchy of basic needs (Figure 2). Maslow’s hierarchy of needs provides teachers with an illustrated version of basic needs that ought to be met for successful teaching and learning to occur. The diagram that follows depicts Maslow’s hierarchy of basic needs.

KEY TO MASLOW’S HIERACHY OF NEEDS
5. Self-actualisation needs
4. Esteem needs
3. Belongingness and love needs
2. Safety needs
1. Physiological needs

Figure 2: Maslow’s hierarchy of needs**.** Adapted from Pollard and Triggs (1997, p. 201)

Maslow's hierarchy of needs provides teachers with an illustrated version of basic needs that ought to be met for successful teaching and learning to occur. Due to the lack of discipline at some schools, rules are compromised and more responsibility is shifted to the learning community which in turn leads to an increase in the division of labour.

In Tulip Secondary the master teacher (Penny) used various strategies to ensure that the learners' behavioural problems that were evident in other classrooms did not manifest itself in her classroom. Whilst Penny used her knowledge gained from her vast experience to make her classroom more conducive to teaching and learning for her learners, she would not necessarily have used these strategies and methodologies if this external activity did not begin to manifest itself in her classroom. The reason Penny did not have a discipline problem in her classroom, as experienced by the other teachers at the school, was that she used diverse teaching strategies and methodologies in her classroom. This included the use of scaffolding, stories, pictures and colour.

The lack of discipline also exhibited itself in Sam's classroom at Carnation Secondary. Whilst this did not hamper Sam in his teaching this was significant. This suggested that Sam could control how the learners behaved within his activity system. He did this by making his classroom milieu more accessible, inviting and conducive to the learning of mathematics. He used pictures, diagrams, concrete manipulative and gestures to attain this atmosphere.

National examinations and testing

An additional external activity system that influenced the activity system within Sam's classroom was that of the national examinations and tests. Regardless of the context of the school, all schools write national examinations and tests. When teaching time is spent on drawing diagrams and levelling out the mathematics 'playing field', this has an impact on syllabus coverage. The added pressure on the teacher of completing the syllabus in a shorter period affects the community within the activity system. The community becomes overworked and the division of labour is unfairly distributed. To overcome this issue Alan and Dean spent many afternoons and weekends at school providing extra classes for their learners in order to complete syllabus and provide support to their learners.

Parental involvement

The sixth theme that was evident was the lack of parental involvement at some schools. For example, the learners who attended Carnation Secondary came from less privileged backgrounds. Whilst the parents wanted their children to succeed in school and obtain the best possible education, the home environments caused conflict with the community and the division of labour within this activity system. Not all parents could provide educational support for their children. Most parents could not afford additional materials and extra tuition to assist in improving their children's educational abilities. This added pressure on the community within the school to provide an environment that supported these needs. This in turn added extra responsibilities on the already overextended teachers at the school. This caused an unfair disadvantage when compared to other schools within the more affluent suburbs of KZN. The division of labour amongst the learning community was unfairly distributed.

CONCLUSION

What came out strongly in the interviews and observations was that whilst the teachers had their own techniques of teaching, their methods were both grounded in tradition and modified as they taught; each master teacher was willing to share their practice. It was through this practice that they could comment on the usefulness and appropriateness of their visual tools for specific sections in mathematics. This resonates strongly with the notions of activity theory, whereby human beings mediate their activities using tools. The results of the study exhibit that the use of visuals as tools within the different activity systems made the abstract nature of certain mathematics concepts more concrete, these tools made certain mathematics concepts easier to remember, and in general the mathematics lessons became more fun and interesting. The high level of student engagement and interaction in the different activity systems seems to indicate that through the use of activity theory the teaching and learning of mathematics was more effective.

A recommendation of the study is that mathematics teachers employ the use of visuals as tools in their classrooms through the use of activity theory as a framework for their lessons. This would make lessons more successful and teachers would achieve their aim of promoting the effective teaching and learning of mathematics.

REFERENCES:

Atweh, B., Bleicher, R. E., & Cooper, T. (1995). Social context in mathematics classrooms: Social critical and sociolinguistic perspectives. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Barab, S., Schatz, S., & Scheckler, R. (2004). Using activity theory to conceptualize online community and using online community to conceptualize activity theory. Mind, Culture and Activity, 11(1), 25 - 47.

Bernstein, B. (1971). Class, codes and control. London: Routledge and Kegan Paul, Publishers.

Boaler, J. (2002). Learning from teaching: exploring the relationship between reform, curriculum and equity. Journal for Research in Mathematics Education, 33(4), 239 - 258.

Engeström, Y. (1987). Learning by expanding: An activity-theoretical approach to developmental research. Helsinki: Orienta-Konsuit.

Engeström, Y. (2001). Expansive learning at work: toward an activity theory reconceptualization. Journal of Education and Work, 14(1), 134 - 156.

Groves, S., & Dale, J. (2004). Using activity theory in researching young children's use of calculators. Paper presented at the Annual conference of the Australian Association for Research in Education, Melbourne.

Howie, S. J. (2003). Language and other background factors affecting secondary pupil's performance in mathematics in South Africa. African Journal of Research in SMT Education, 7, 1 - 20.

Jonassen, D. H. (2002). Learning as activity. Educational technology, 42(2), 45-51.

Jonassen, D. H., & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. Educational Technology Research and Development, 47(1), 61 - 79.

Kotze, G. S., & Strauss, J. P. (2006). Contextual factors of the mathematics learning environments of grade 6 learners in South Africa. Pythagoras, 63, 38 - 45.

Makapela, L. (2007). Dinaledi schools making progress. Retrieved 13th October 2008, from South Africa. info. Gateway to the nation http://www.southafrica.info/about/education/dinaledi-161007.htm

Maschietto, M., & Bartolini Bussi, M. G. (2009). Working with artefacts: gestures, drawings and speech in the construction of the mathematical meaning of the visual pyramid. Educational Studies in Mathematics, 70, 143 - 157.

McLoughlin, C. (1997). Visual thinking and telepedagogy. Paper presented at the ASCILITE, Perth, Australia.

Mwamwenda, T. S. (2004). Educational psychology. An African perspective. Sandton: Heinemann Higher and Further Education.

Naidoo, J. (2006). The effect of social class on visualisation in geometry in two KwaZulu-Natal schools, South Africa. Education. University of Nottingham. Nottingham.

Naidoo, J. (2012). Teacher reflection: The use of visual tools in mathematics classrooms. Pythagoras, 33(1), 1 - 9.

Pollard, A., & Triggs, P. (1997). Reflective teaching in secondary education. London: Cassell.

Presmeg, N. C. (1997). Generalization using imagery in mathematics. In L. D. English (Ed.), Mathematical reasoning. Analogies, metaphors and images (pp. 299 - 312). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Reddy, V. (2005). State of mathematics and science education: Schools are not equal. Perspectives in Education, 23(3), 125 - 138.

Reddy, V. (2006). The state of mathematics and science education: schools are not equal. In S. Buhlungu, J. Daniel, R. Southall & J. Lutchman (Eds.), State of the Nation. South Africa 2005 - 2006. (pp. 392 - 416.). Cape Town: HSRC, Publishers.

Rezabek, L. L. (2008). Why visual literacy: Consciousness and convention. TechTrends, 49(3), 19 - 20.

Sfard, A. (2009). What's all the fuss about gestures? A commentary. Educational Studies in Mathematics, 70, 191 - 200.

Solano, A., & Presmeg, N. C. (1995). Visualization as a relation of images. Paper presented at the 19th Conference of the International Group for the Psychology of Mathematics Education, Brazil.

Steer, J., de Vila, M. A., & Eaton, J. (2009). Trigonometry with year 8: Part 1. Mathematics Teaching, 214, 42 - 44.

Van Garderen, D. (2006). Spatial visualization, visual imagery, and mathematical problem solving of students with varying abilities. Journal of Learning Disabilities, 39(6), 496 - 506.

Zevenbergen, R. (2001a). Language, social class and underachievement in school mathematics. In P. Gates (Ed.), Issues in mathematics teaching. (pp. 38 - 50). London: Routledge Falmer Publishers.

Zevenbergen, R. (2001b). Mathematics, social class and linguistic capital: An analysis of mathematics classroom interactions. In B. Atweh, H. Forgasz & B. Nebres (Eds.), Sociocultural research on mathematics education (pp. 201 - 215). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.