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# Activity Theory as a framework for understanding teachers' perceptions of computer usage at a primary school level in South Africa

**Joanne Hardman**
jhardman@humanities.uct.ac.za

Educational underachievement in gateway subjects such as mathematics and science is a continuing challenge in South African schools. In a bid to develop technologically competent mathematicians and scientists while addressing the shortage of teacher capacity in the country, the government has turned to computer technology to support and strengthen teaching and learning in disadvantaged classrooms. The assumption underlying the use of computers in these schools is that computers will enable students to cover the curriculum more efficiently and effectively, leading to improved performance. However, the extent to which a computer can impact positively on students' achievement depends on how a computer is used as a learning/teaching tool. I seek to illustrate the potential use of Activity Theory as a framework for understanding how teachers use technology to mediate the teaching and learning of mathematics in primary schools. To this end, I argue for an understanding of the notion of an 'object' as a methodological concept capable of tracking shifts within and between activity systems. Drawing on interview data collected from four case studies carried out in the Western Cape, South Africa, an account of teachers' perceptions regarding how pedagogy shifts across the different contexts of the traditional lesson and the computer laboratory is developed. I conclude by arguing that the strength of Activity Theory lies in its ability to enable one to understand learning as the complex result of tool-mediated interactions, rather than as something opaque, which happens in a student's mind.

## Background and research questions

"Pedagogics is never and was never politically indifferent, since, willingly or unwillingly, through its own work on the psyche, it has always adopted a particular social pattern, political line, in accordance with the dominant social class that has guided its interests" (Vygotsky, 1997b:348).

It is over 70 years since the insightful psychologist, Vygotsky, first published the above quote. Much has indeed changed since these sentiments were committed to paper; we live in a world today that would be barely recognisable to this author. The current incredulousness towards grand narratives and indeed the announcement of the 'end of history' (see Fukuyama, 1992) suggests, perhaps, that we live in a time far removed from the issues highlighted in this quote. Whether or not we live in a time characterised by postmodern *angst*, however, Vygotsky's conceptualisation of pedagogy continues to provide a useful reminder to those of us studying pedagogical practices that we need to be cognisant of the socio-historic conditions allowing for the production of new knowledge and new practices. This is particularly relevant in post apartheid South Africa, where the introduction of the new curriculum aimed to build democratic classrooms where knowledgeable teachers work with active students to construct new possibilities for knowing, and, indeed, for being — see the Revised National Curriculum Statement (RNCS) and the Norms and Standards for Educators (2000) for a detailed description of the types of teachers and students envisaged in the policy documents (Department of Education, 2002).

March 1997 saw the launch of Curriculum 2005 (C2005) marking a departure from content to outcomes based learning, signalling a break with the past and a move from fundamental pedagogics to progressive pedagogy underpinned by a learner centred approach to teaching and learning. The need to move away from a curriculum that separated mental and manual work or academic and vocational training was recognised in the curriculum's focus on the integration of education and training. The ideological thrust behind Curriculum 2005 is outlined in the White Paper on Education and Training (1995) and the South African Schools Act (1996) and can be briefly summarised in the following points:

- Commitment to providing quality education for all
- Developing democratic citizens, equipped with the essential skills required to participate in the knowledge economy of the 21st century
- Redress past inequities by providing for new learning/teaching strategies to enable the flexible delivery of services across diverse learning contexts by providing access to and equitable distribution of technological resources
- A focus on learner-centred, outcomes based approaches to education.

The new curriculum, in the form of Curriculum 2005, embodied many of these ideals, resulting in a drastic form of learner-centeredness that soon appeared to disadvantage the very students it was constructed to promote, namely, underprivileged second-language students in under-resourced schools with inadequately prepared teachers (Muller, 2000). The Review Committee into Curriculum 2005 Report (Chisholm *et al.*, 2000) consequently found that Curriculum 2005 was over-designed and under-stipulated. In its attempt to pursue a policy of integrating subjects and real world material, Curriculum 2005 rendered the sequence, pacing and evaluation requirements of the gateway subjects of language, mathematics and science opaque to teachers and students alike resulting in poor student progression (Vinjevold &Taylor, 1999; Chisholm *et al.*, 2000). One main lesson of the Review was therefore that explicitness of the learning and evaluation requirements could not, under present South African conditions of learning, be sacrificed in the name of learner-centeredness without impairing learning, a lesson now embedded in the recently released National Curriculum Statement for Grades 1–9. Coupled with South Africa's staggeringly poor performance[1] on the Third International Mathematics and Science Study (TIMSS) test (Martin *et al.*, 2000), the Review indicated a definite need to develop teaching and learning capacity, especially in mathematics and science. To meet this challenge in previously disadvantaged schools in the Western Cape, the government, under a project initiative called the Khanya Project,[2] has turned to computer hardware and software in a bid to both provide teachers with the support they need to teach as well as provide students with stimulating software environments to re-engage waning mathematical interest.

The assumption underlying the introduction of computers into schools is the understanding that computers can impact positively on performance and heighten student motivation, facilitating the re-engagement of student interest in subjects such as mathematics (Dwyer, 1994). However, whilst there is certainly ample large-scale research (Dwyer, 1994; Jurich, 1999; Kulik & Kulik, 1991; Software Industry Information Association (SIIA), 2000; Wenglinksy, 1998) to suggest that this is the case, there is a current dearth of in depth case study type research suggesting exactly how teachers use computer software and hardware as tools to develop students' mathematical understanding and in what ways the introduction of the computer into the lesson forces a change in pedagogical practice. The need to understand the processes underpinning teachers' appropriation of a novel technology arises out of a body of research indicating that it is not the computer itself that is responsible for positive learning gains, but rather how the computer is used by a teacher (Cox *et al.*, 2005). Teachers' perceptions, goals and beliefs in relation to computers impact heavily on how computers are used as teaching/learning tools (Russell & Schneiderheinze, 2005). Previous research into how computers are used in schools has suffered the following limitations: 1) they fail to account for the teacher's epistemic assumptions regarding the novel technology, 2) they lack a sufficiently nuanced understanding of the social, historical and contextual structures that inhere in an environment, and 3) they do not deal with the relationship between tools within the context of their use, leading to a failure to appreciate that use of a novel tool is almost certainly contingent upon how other tools in the system are used (Russell & Schneiderheinze, 2005). I will attempt to meet these challenges by situating the study within an Activity Theory framework in order to develop an understanding of classrooms as complex social systems. In a bid to understand how teachers appropriate the computer as a teaching/learning tool, I begin to unpack teachers' perceptions around computer use and seek to:

1. Construct a picture of activity systems across traditional and computer classrooms;
2. examine the extent to which these systems differ, by focusing on whether the object of the lesson changes across the two contexts. This question arises out of my understanding that the introduction of a novel tool into a context can be expected to create changes in that context; and
3. address the following methodological question arising from engagement with the preceding research questions, namely: how does one go about tracking potential pedagogical shifts in a classroom?

Reconstituted in the language of Activity Theory , I seek then to understand whether the introduction of a computer has the potential to force a change in the activity systems of classrooms, challenging stabilised (operationalised) ways of acting on the object of each system and, consequently (hypothetically), requiring new ways of acting. The focus on teachers is driven by the understanding that the pedagogical component is central in understanding the implementation of novel technology (Noss & Hoyles 1996). In order to address these questions I report on data drawn from four case study schools in the Western Cape, South Africa.

## Psychological tools and mediated learning

### The theoretical basis for understanding human computer interaction

The new Curriculum has set the stage for a move in South African pedagogy from a predominantly transmission model of learning, where skilled teachers view children as empty vessels easily filled with knowledge, to an understanding of learning that appreciates that students are much more actively involved in constructing knowledge (Kozulin, 2003). In their search for alternative models to explain learning, many researchers have turned their attention to Vygotsky's notion of mediation, where a more competent peer or adult is viewed as assisting performance, bridging the gap between what the child knows and can do and what the child needs to know. Vygotsky (1978) conceptualised this gap between unassisted and assisted performance as the zone of proximal development (ZPD) that 'space' where learning leads to development (Vygotsky, 1978; Gallimore & Tharp, 1993; Moll, 1993; Cole, 1985; 1996; Daniels, 2001; Diaz *et al.*, 1993). Crucially, for Vygotsky (1978) (and indeed for all activity theorists who have followed in his footsteps) human consciousness is social (Nardi, 1998). What we have here, then, is a theory that overcomes the Cartesian dualism currently permeating various powerful paradigms in human computer interaction research such as cognitive science, which continues to locate cognitive functioning within the rational individual (Hardman, 2004). Essentially, Vygotsky enables us to conceptualise the prior existence of complex cognitive structures as existing in the child's culture, rather than in the individual child. Every experience, then, that the child has is mediated through cultural tools. Figure 1 illustrates the basic Vygotskian triadic representation of mediation, where the subject acts on the object using mediational means (tools).

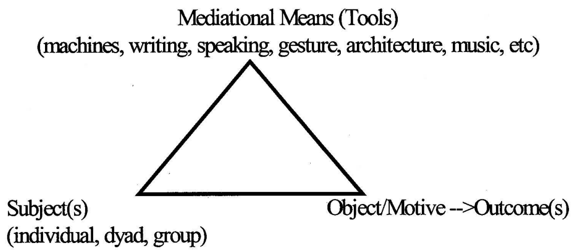


Figure 1 First generation Activity Theory

For Vygotsky (1978) humans use tools to change the world and are themselves transformed through tool use. While this representation opens the way towards an understanding of learning as transformation rather than transmission, it lacks an articulation of the individual subject and his/her role in the societal structure. Activity Theory as developed by Engestrom (1987; 1996) takes the object-oriented, tool mediated collective activity system as its unit of analysis, thereby bridging the divide between the subject and the societal structure (Daniels, 2001). It is this Activity Theory tradition that has been taken up enthusiastically by those working with human computer interaction (Bodker, 1989, 1991; Kaptelinin, 1996; Nardi, 1996; Zinchenko, 1996; Russell, 2002). If we think of computers as cultural tools, then we need to be able to ask and answer questions related to how these tools facilitate learning and, relatedly, how teachers and students change the computer and are transformed by it over time. Activity Theory can be used in order to understand this process of transformation within a system (such as a classroom) as well as illustrating how different systems interact with, and transform each other over time (Engestrom, 1987). The strength of Activity Theory is that it enables one to understand learning as the complex result of tool mediated interactions, rather than as something opaque which happens in a student's mind.

### Basic principles

Whilat Activity Theory is best understood as a developing body of knowledge, there are some basic principles that are shared by those working within the field. I draw primarily from Cole (1996) and Russell (2002) in order to elaborate these principles:

- Human activity is collective and human behaviour originates within the social realm (Cole & Engestrom, 1993).
- Mind is social, growing out of joint activity.
- Tools, which carry socio-historical meanings, mediate our psychology.
- Activity Theory studies development and change, which is understood to include historical change, individual development and moment-to-moment change (Russell, 2002). When studying computer mediated learning it is important to focus on all three levels of change in order to construct a picture of human computer interaction.
- Activity Theory assumes that people are active cognising agents but that they act in sites that are not necessarily of their choosing with tools that constrain and afford their actions.
- Methodologically, Activity Theory rejects cause and effect explanatory science in favour of "a science that emphasises the emergent nature of mind in activity and acknowledges a central role for interpretation in its explanatory framework" (Cole, 1996: 104). Consequently, activity theorists make use of a contextualist methodology.
- Activity systems are constantly subject to change and Activity Theory sees these changes as driven by contradictions (Engestrom, 1987; Russell, 2002). Contradictions, or double binds, can arise within and between systems.

## An activity system

For Activity Theory the basic unit of analysis is an activity system. Briefly, this refers to a group of people, or a community, who share a common object (or problem space) and who use tools to act on that object, transforming it. In Figure 2, the object is represented as a circle indicating that this space is subject to change and is in a state of flux, making it difficult to pin down. Relationships in this system are driven by rules, which both afford and constrain behaviour. Rules can be understood as principles of control. Division of labour within the system describes both a horizontal division among community members, as well as a vertical division between power- and status-holders. Division of labour, then, can be understood as related to power within and between systems. Figure 2 elaborates the basic relationships in an activity system.

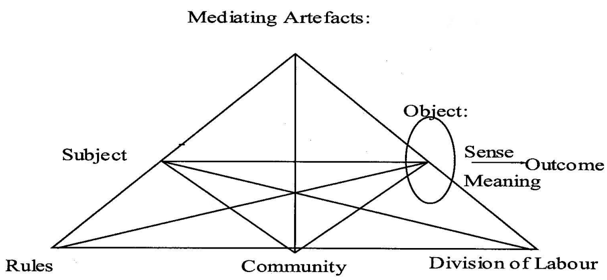


Figure 2 An activity system

## Methods and techniques

The findings presented in this article are drawn from a wider project, where I followed four teachers and their Grade 6 mathematics classes over the course of a year. Whilst video data as well as student interview and questionnaire data were collected for the project as a whole, this article deals specifically with interview data collected from the four case study teachers involved in the research. The rationale for focusing on these data derives both from time and space constraints of article construction as well as from the methodological need to develop a coherent account of how one studies technological innovation and its impact at the level of teachers' perceptions as well as at the level of actual practice. How teachers understand and approach a novel tool will depend on their perceptions regarding it. Consequently, in order to understand how teachers' appropriate the computer as a teaching/learning tool, one must first understand teachers' perceptions of the novel tool. Here I develop a line of argument to suggest that a first step in tracking pedagogical shifts empirically begins with understanding teachers' perceptions of what it is they are working on and what motivates them to use tools to act on problem spaces. That is, before one attempts to track pedagogical shifts within an actual classroom, one needs to develop a picture of what the potential object of the lesson will be, in order both to identify and track this emerging object.

*Selection of the schools*

As this research was concerned primarily with answering a process type question, I adopt a case study approach to data collection. The strength of a case study approach lies in its ability to provide thick descriptions of the complex phenomena under investigation (Denzin, 1989; Yin, 1993; 1994; Cohen *et al.*, 2000). In this study, four Grade 6 classrooms across four schools in the Western Cape were the cases under study. The study was located within mathematics classrooms, due more to the fact that computers are being used more frequently in these classes in order to impact student performance, than to any bias on the researcher's behalf towards mathematics classes. Cases were selected using replication rather than sampling logic, with the primary selection requirement being the exemplary use of computers in the school within the following parameters:

1. The student profile was one of disadvantage (where 'disadvantage' refers to low socio-economic status as determined by the proxy variable of school fees)
2. The school functions well, where 'functioning' refers to the presence of a management team and structured time tabled lessons.
3. Computers are used to teach mathematics for at least 1 hour per week.
4. Schools are located in rural and urban areas.

*Participants*

As this study sought to investigate the potential shifts in pedagogical practice that arise from the introduction of a novel tool into the teaching/learning context, the subjects of this study are four primary school mathematics teachers. Table 1 represents the demographic data collected from the teachers. The two male and two female teachers participating in the study are coloured Afrikaans first language speakers who have been teaching from between two to fifteen years. The two male teachers have a matric plus 4–5 years teacher training whilst one of the female teachers has a matric plus three years training. The youngest teacher in the sample has a bachelor's degree.

*The instructional context*

This study was located within four Grade 6 mathematics classrooms in two rural and two urban schools which could be referred to as having a predominantly 'coloured'[3] student body. All schools in the sample could best be described as disadvantaged, with school fees (a proxy for socio-economic status) ranging from R30 to R240 per annum. The two rural schools, which are located outside Cape Town, could best be described as 'farm' schools. All the schools reported that schools start at 8.00 in the morning and finish at 14.00 in the afternoon. The first language of the majority of students in all schools is Afrikaans; in schools A, B and C, the minority group speak Xhosa and in school D the minority speak English. Periods last from between 30 and 50 minutes. School C and B have 9 mathematics periods per week; school D has 5 and school A has 10. All schools use the computers for teaching mathematics to Grade 6 students; however, the amount of time used differs across schools, with school A using the computer for 60 minutes per week; school B 120 minutes; school C 80 minutes; and school D 50 minutes. Class (and grade) sizes differ across the schools; in Grade 6 in school A there are 50 students in each class; in school B, 30; in school C, 48 and in school D, 43. No examinations are written at any of the schools; continuous assessment based on defined outcomes forms the basis for assessment.

*Procedure*

The data collected for this article consist of interviews gathered from the four participating teachers. Interviews with the participating teachers were conducted after observations of both two traditional lessons and two computer lessons, i.e. each teacher was interviewed twice. These interviews lasted between 45 minutes and one and a half hours, depending on the individual teacher's engagement with the questions. The interviews were tape-recorded and transcribed within one hour of the recording by the researcher. As the researcher is bilingual, all participants were given the choice of responding to the interview questions in either English or Afrikaans. Whilst all the teachers spoke Afrikaans as a first language, only one teacher opted to be interviewed in Afrikaans.

*Analysing the interviews*

A semi-structured interview schedule was used to guide the discussion. The questions were open ended in order to encourage the respondents to develop a narrative around teaching with computers. Questions probed the teacher's epistemic assumptions regarding teaching and learning mathematics as well as the teacher's thinking about the use of computers as teaching/learning tools; the use of ICT and non-ICT tools; rules in the traditional and computer classrooms; division of

**Table 1** Teacher demographic data

| Demographic details | Teacher A | Teacher B | Teacher C | Teacher D |
|---|---|---|---|---|
| Gender | Male | Male | Female | Female |
| Age | 30–39 | 30–39 | 40–49 | 30–39 |
| First language | Afrikaans | Afrikaans | Afrikaans | Afrikaans |
| Highest level of formal training | Matric + 4/5 years teacher training (e.g. FDE) | Matric + 4/5 years teacher training (e.g. FDE) | Matric + 3 years teacher training | Bachelor's degree and teacher training (e.g. HDE) |
| Years of teaching | 2–5 years | 11–15 years | 15 + years | 6–10 years |
| Grade levels taught in the past 5 years | Grades 5, 6 and 7 | Grades 6 and 7 | Grades 6 and 7 | Grades 5, 6 and 7 |
| Home computer | No | Yes | No | No |

labour; motives for acting on objects and the objectives of ICT and non-ICT lessons. The transcribed text was analysed in terms of categories drawn from Activity Theory, namely: subject position; tools; object; rules and division of labour. Of particular interest for this study was teachers' positioning of themselves in relation to technology. This positioning enabled me to track the objects in the activity systems, as well as providing an account of teachers' perceptions of the impact of technology on the teaching and learning of mathematics. The following questions guided the analysis:

1. How do teachers mobilise their perceptions to construct the activity systems of the classroom and the computer laboratory? What do these activity systems look like?
2. What object(s) is/are the teachers working on when they use the computer?
3. Does the object shift across the different contexts and does this enable us to construct two different activity systems: one representing the teachers' description of the traditional classroom and one representing their description of the computer laboratory?

Analysing all the data with well-defined categories derived from Activity Theory went some way towards ensuring the reliability of the analysis. However, in order to ensure that the categories were not idiosyncratically imposed, a graduate student whose research falls within an Activity Theory framework analysed the interviews independently. Agreement across the categories of tools, object, rules and division of labour for teachers A, B and D was reached. However, there was some disagreement between us regarding the shifts in division of labour articulated by teacher C, necessitating a further discussion with this teacher. Whilst reliability issues were dealt with by a graduate student and me, validity issues necessitated checking my interpretation of the responses with the respondents.

*Understanding the object as a methodological concept*

Whilst Activity Theory continues to develop and grow, one of the general assumptions held by all authors located within the field is the comprehension of the object as that space which enables one to understand the activity system as a whole (Engestrom, 2001; Leontiev, 1981). Consequently, being able to identify and track the object (or objects) of an activity system enables the researcher to elaborate the system as a whole. However, the simultaneously material and ideal nature of any object makes it extremely difficult to uncover the object of any system (Foot, 2002). Nevertheless, the object is intricately related to the subject (to the extent that the subject acts on it to construct and transform it) pointing methodologically, to the importance of understanding the subject's position when tracing the object (Popova & Daniels, 2004). Therefore, in order to develop an activity system that could provide a useful unit of analysis, teachers were interviewed with specific attention paid to unpacking their understandings of the object(s) of the activity systems they inhabit in both the traditional and computer classrooms.

## Results

### What objects do teachers think they are working on in face to face lessons?

Teachers' perceptions of how they mediate the teaching and learning of mathematics in face to face classrooms and in computer classrooms were elicited during the interviews. Whilst there were differences between teachers' individual approaches to computer use and, indeed, pedagogical practices, it was possible to develop a representation of general patterns that emerged from the interview data.

**Object**: The object of an activity system is that problem space that the subject acts on and transforms. In Extract 1 it is interesting to note that all teachers indicate that they are working on developing students' understandings of abstract mathematical concepts, with teachers A, B and D indicating that they do this by moving from the familiar to the unfamiliar. The focus is on providing children with subject knowledge that can equip them to use maths in their adult lives. Reconstituted in the language of Activity Theory, the object of this activity then, is children's 'scientific'[4] or 'schooled' concepts (Kozulin, 2003).

### Extract 1: The object of the face to face lesson

**Teacher B**: *In this class, um, today, we are working on fractions. So, I am trying to use concrete things, things they know from their homes, like apples, to get them to understand fractions, which are very abstract for them. So that's why I use those apples, concrete things, and then you can build it from there, from the concrete apple to the more abstract fractions*

**Teacher A**: *OK, we are working on shapes and they must sit in their group and draw a man using the shapes they have learned before.*

**Teacher C**: *So first I explain and then they work in their groups. And they can discuss, they must discuss the problem. So here it is solving these fractions. They must be able to add for example, to say what is an ½ of ¼.*

**Teacher D**: *First I introduce and then they must do the activity. Today you saw, today we did that shapes. So they have the shapes of the car or the house and they must use those, they must use the paper shapes to understand now: what is a shape. You know? Now what is a triangle, now where can I see that in the class? So I also ask them those things. And I tell them to go home and to look and see, now where do I see a pentagon in my kitchen or something like that. So I understand it like this, that they must be active and they must use what they know because for them, you see, mathematics is quite difficult. So you must always say, no look here, this square it looks like the window. So you have seen it before but now you must know that is has four equal sides. So you must learn something new from what you know.*

**Tools**: All teachers indicated that they use the blackboard and "activities" as tools to act on and transform children's mathematical concepts. In this instance, activities refer to tasks that children generally are required to carry out in small groups. Group work, then, becomes a tool that teachers use to develop conceptual understanding.
**Rules**: The teachers' predominant focus on transforming children's scientific concepts is influenced by current social rules and regulations that both support and constrain activity. In this instance, the current policy shift from traditional pedagogy to outcomes based pedagogy and the consequent shift from a focus on passive to active students impacts on the types of tools teachers select to act on students' scientific concepts. These rules in turn influence a teacher's subject position, ultimately informing a teacher's epistemic assumptions regarding teaching and learning.
**Division of labour**: Within a traditional lesson, division of labour generally sees the teacher as controlling the pace, sequencing and selection of the lesson. Power tends to rest almost exclusively with the teacher, with the traditional IRE sequence of teacher initiated interaction predominating (Cazden, 1986). The teacher's role is one of teaching and the students' are expected to learn.
**Community**: Teachers indicated that, whilst they appreciate the wider community of teachers to which they belong, they consider the classroom community comprises only themselves and their students.

The activity system of the classroom, as described by the four case study teachers is represented graphically in Figure 3. By identifying the object of the traditional mathematics lesson (mathematical concepts), we are able to generate a picture of the entire system, i.e. driven by their understandings of mathematics as actively learnt, teachers use various tools, such as the blackboard or textbooks, to transform children's current mathematical understandings (of fractions or space and shape, in this study) in order to develop mathematically literate students. The predominant focus on developing understanding means that the teachers tend to occupy the role of didact, with control over teaching and learning inhering in the teachers' rather than the students' role. The question that arises now is the extent to which this particular object remains constant across the different contexts and, consequently, the extent to which the computer and traditional classrooms can be constructed as different activity systems. .

### What object(s) do the teachers think they are working on in the computer laboratory?

The above discussion suggests that teachers believe that they are working on transforming children's conceptual grasp of mathematics in their face to face lessons. Given the introduction of a novel tool (the computer hardware and software) into the lessons the interesting question now becomes the extent to which this tool either constrains or facilitates the teachers' practice.
**Object**: In Extract 2, one can see both B and D indicating that the object space they are working on in the computer laboratory is not in fact students' understanding of scientific concepts, but, rather, the computer itself. It is also clear that the computer is used for drill and practice purposes rather than for the development of higher cognitive purposes.

### Extract 2: The object of the computer laboratory

**Teacher A**: *I use it for practice, to practice what they did in the class. This is the best thing for them because you can't just give them homework, give it to them and you lucky if you get even ⅓ of the class bringing it back!*
**Teacher B**: *OK.... So they have to learn how to use the computer, and, I would say, ja, that I have to teach them computer skills as well as maths in this lesson.*
**Teacher C**: *I don't think it's a tool for learning in that sense. It's good for practicing, it's a good skill. But I am not sure about learning.*
**Teacher D**: *Uh, and I think it's very good for the children to be able to practice what they have learnt in class on the computer and to learn the computer, to learn to use it.*

Given the current hope that computers will be used as cognitive tools to effect transformation on children's mathematical understanding, the fact that teachers appear to operate on different objects within the computer maths lessons seems initially quite problematic. All teachers in the sample went on to indicate that the computer is indeed used as a tool, but, rather than being used as a higher order cognitive tool, it is used as a tool to motivate children (Extract 3) and, indeed, in a very real sense it serves a social justice function, giving previously disadvantaged students access to a world outside of their immediate context. Motivation, any teacher will tell you, is a key element in learning. Consequently, whilst the computer may not be serving its intended purpose as a cognitive tool mediating higher order problem solving skills, it is still serving as a tool to grab students' attention and re-engage their desire to learn mathematics.

### Extract 3: The computer as a tool for acting on children's levels of motivation

**Teacher A**: *It is exciting for them. So in that sense, if we can use it to make them interested in maths, ja, then in that sense it is very useful.*
**Teacher B**: *It is actually a tool that we can use to, to it's like a carrot keeping it in front* (dangles his pen in front of his face) *... I mean their world is very small. So what the computer do is it helps them, ... to see actually more of what is happening.*
**Teacher D**: *I think they get more motivated, more excited to do maths.*

However, whilst all teachers indicated that the computer is at best a low level cognitive tool capable only of motivating students to re-engage with mathematics, teacher B indicated that the computer has the potential to widen students' horizons. In Extract 4, teacher B suggests that the computer gives students access to a world outside of their own immediate context, providing them with the possibilities to engage with knowledge. What one sees here is the potential the computer has to open up students' zone of proximal development by giving them access to knowledge outside of their current understanding. It is, however, unclear from this extract whether the computer is able to provide the kind of guided assistance students will need in order to learn within the ZPD. The mere provision of opportunities to open students' ZPD says little about teaching/learning within this zone.

### Extract 4: Opening the Zone of Proximal Development?

**Teacher B**: *Let's let's take for example these kids world is very small and I mean very small. Some of them have never seen across the mountain. They haven't seen the sea and if I am honest with you, last year a teacher came into my class from Grade 1 and she said "you know what 6 of the kids in my class haven't seen town!'. And I said, it can't be it's just down the road — and she said um and some of them they do go to town but what they got to do they sit in the lorry and watch mom's stuff because someone else will take it away. So that is their view ... so that's what I mean their world is very small. So what the computer do* [sic] *is it helps them, especially Encarta, to see actually more of what is happening. What I did last year, is to show them say we talked about America especially we can now talk about Iraq what's happening, can show them quickly, now here's Iraq this is what's happening. This is a war. We had a war, Vietnam war just watch what's happening.*
**Tools**: In the computer classes the teachers use the computer as a tool to motivate students and to broaden their horizons. Three of the teachers indicated that they use student interaction as a tool in the computers classes, encouraging students to share information with each other in order to problem solve. This increased student on student interaction in turn impacts on shifts in division of labour, with students becoming peer teachers.
**Rules**: Strict rules of computer usage are followed in the laboratories. Teachers' own relative inexperience with the computer leads them to control students' engagement with the novel technology by limiting students' exploratory behaviour.
**Division of labour**: Research has shown that the use of computers and cooperative learning methods affects the roles of teacher and students

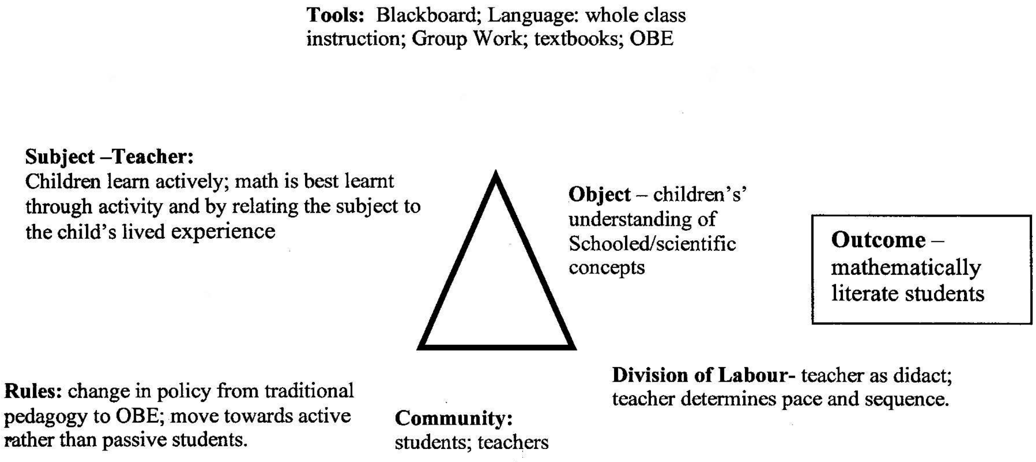


Figure 3 Teachers' description of the activity system of a face to face lesson

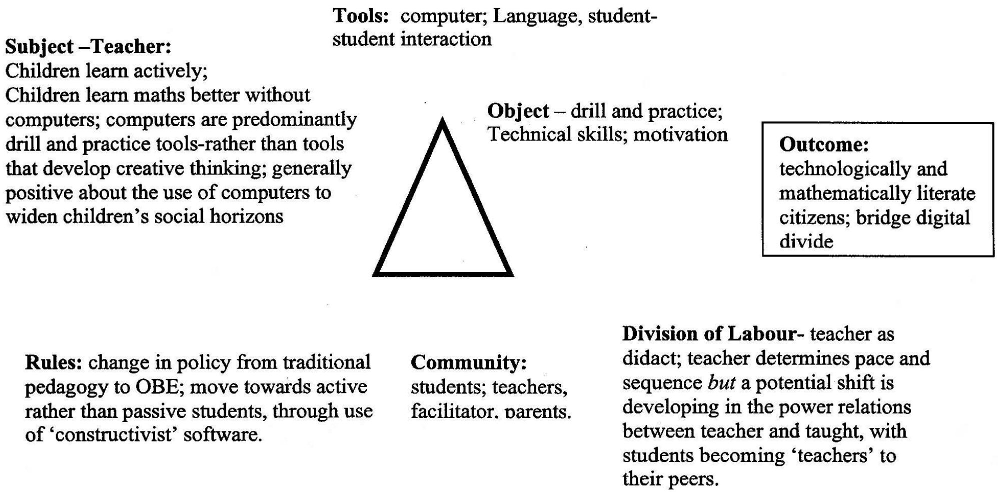


Figure 4 Teachers' description of the activity system of a computer classroom

(Cohen, 1994; Mercer & Fisher, 1993; Fish & Feldman, 1989), with the teacher becoming more of a facilitator and students directing their own pace and sequencing; i.e. the introduction of the computer forces a shift from a teacher centred to a student centred approach. As C2005 is committed to developing active students who drive their own learning, clearly if the computer can be used to achieve this it will go some way towards meeting the needs of the new Curriculum. Extract 5 indicates that teachers are somewhat divided in their views about the shift in division of labour in the computer class, with teacher B indicating that he is still very much in charge of the lesson, and teachers A and D indicating that the computer has indeed introduced a shift in roles in their classes, with students becoming teachers of "slower" students. Teacher C goes even further, suggesting that the students have something to teach her; here her role shifts from teacher to learner.

### Extract 5: Division of labour in the computer laboratory

**Teacher B**: *It* [computer] *can't help on its own, it can't teach. No, I am still the teacher in the classroom.*
**Teacher D**: *... like I said before, there are exercises for weak children and for faster children. Like Henry, he and Rendell and that group, they are a group that will always finish quickly and put up their hand and say Miss I'm finished and I say OK, go to Grade 7 work. And then they can also help the others, those going slower.*
**Teacher A**: *When they finished with the work, when they finished the exercise, then, they help, they can talk to each other. They sit in pairs, so they can talk to each other or get up and help their friend.*
**Teacher C**: *... and sometimes I think, yow!, these children, no I can learn from them! You know? They know this thing* [computer] *much better than me.*

**Community**: The computer has widened the classroom community to include parents (who learn to use the computer after hours), a facilitator (who provides teachers with technical assistance on a weekly basis), the software designers as well as the teacher and students. It is here, perhaps, that further investigation into the computer's ability to act as a teaching/learning tool within students' ZPD needs to be carried out.

Figure 4 is a graphic representation of teachers' descriptions of the activity system of the computer laboratory. It is clear that the object being worked on in the laboratory is technical, computer skills, drill and practice skills, as well as students' motivation. A potential shift in the division of labour is also evident, with students beginning to tentatively occupy the role of 'teachers' of their peers.

## Discussion

In this article I set out to examine teachers' perceptions of computer use in their classrooms using an activity theory framework to 1) construct a picture of activity systems across traditional and computer classrooms, 2) to examine the extent to which these systems differ, by focusing on whether the object of the lesson changed across the two contexts and, 3) to develop/refine a methodological tool capable of tracking pedagogical shifts across the two contexts. The data reported enabled the construction of two distinct activity systems; one representing the traditional mathematics classroom and the other representing the computer classroom. Further, the data indicate that there are indeed differences between the teachers' descriptions of traditional and computer lessons. Activity Theorists (Engestrom, 1987; Russell, 2002; Nardi, 1996) suggest that when one wants to track shifts in a system, one should focus on the extent to which the objects change, as systems change when their objects change. Consequently, focusing on the object of the lessons enables one to see that two distinct systems are indeed in operation in this study, with two separate objects. Focusing on the objects as a tool for tracking pedagogical shifts provides one with a lens through which to develop a picture of the entire system, enabling one to construct a picture of the two distinct activity systems.

The assumption underlying computer use in schools is that the computer will be used as a cognitive tool to impact on students' performance. Consequently, the object of the computer based maths lesson is assumed to be students' scientific (mathematical) concepts. However, findings from interviews with teachers indicate that teachers believe that the object of the computer lesson appears to be lower order cognitive skills (such as drill and practice), rather than the anticipated higher order conceptual development promised by the novel technology. At first blush this finding appears to call into question the need to use computers in schools. However, this conclusion fails to take into account the various dimensions of learning. Research (Halpern, 2004) would certainly seem to point to the need for practice (which should be varied and challenging) when laying down memory traces; a necessary condition for successful academic engagement. Consequently, the fact that the computer is used to act on lower order skills should not lead us to assume that it is not serving an extremely important cognitive function. More important, perhaps, and certainly more interesting, is the finding that the computer laboratory leads teachers to act on different objects than the traditional classroom would appear to enable them to. South Africa continues to struggle against the inequities of the past and in its ability to bridge the digital divide, providing underprivileged children with access to a world outside the narrow confines of their own, the computer is undoubtedly perceived as immensely successful in these schools. Importantly, as a tool that can potentially act on children's motivation, the computer has the potential to re-engage children in learning mathematics, a crucial first step to developing creative students who are interested in mathematics.

This article emerged from the need to construct a picture of traditional and computer classrooms as activity systems, from teachers' descriptions of their individual teaching/learning contexts. Findings presented here suggest that teachers in this study view the computer as both a tool and the object of their lessons. As a tool, the computer is used to transform students' levels of motivation in regard to mathematics; as an object, it is the computer itself that becomes the problem space to be worked on in lessons. These findings would certainly seem to suggest that the introduction of the novel computer technology into disadvantaged schools is impacting on pedagogy, leading to shifts in established practices. However, as the interview data are self-reported data, they are not sufficiently robust to enable one to make pronouncements about actual practice. What I am able to do with this finding is impose these activity systems, as analytical grids, onto the observational data in order to see whether there are differences between the teachers' perceptions of the systems they inhabit and the actual systems they inhabit.

## Conclusion

The study reported on in this article forms part of a larger study that sought to understand how teachers use computers to mediate mathematics teaching and learning at a primary level and whether the novel technology forces shifts in pedagogical practices. Methodologically, it is challenging to study pedagogical shifts across contexts. One possible way of tracking pedagogical shifts across the dynamic environments of a traditional and computer mediated mathematics class, is to track shifts within the object(s) of the activity system. The difficulties of identifying emergent objects within activity systems, however, necessitate methods of data collection that enable one to both identify a subjects' motives for acting, as well as identifying what the problem space is the subject acts on. A potentially promising way of doing this is to interview the subjects in order to develop an analytical grid that can be used to interrogate observational data; a strategy adopted in this study. Findings from this study indicated that teachers' believe that they act on different objects across the different contexts of traditional and computer based mathematics lessons. Whilst teachers indicated that they act on children's scientific concepts in the face to face mathematics lessons, they suggested that in the computer mathematics lessons the object of the lesson becomes computer usage itself. Whilst this finding might appear problematic, in light of the current move in South Africa to improve students' outcomes in mathematics through the use of computer technology, it needs to be viewed as a first step towards understanding the process of computer usage in schools in South Africa. As tools, teachers indicated that computers can be used to motivate students to re-engage with mathematics, an important aspect of learning. Activity Theory 's ability to identify emergent objects within and between systems, thereby enabling a researcher to understand the system as a whole, provides a powerful framework for illustrating how the use of different tools across different contexts impacts on pedagogical practice.

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## Notes

1. The international average score for 38 countries was 487 points; South Africa's average was 275 points.
2. The project aims to:
   - Address the shortage of teacher capacity (particularly in mathematics) through harnessing technology to support and strengthen the education system;
   - create a structure within which to co-ordinate the efforts of various sectors, managing and co-ordinating the financial contributions across these sectors;
   - bridge the digital divide between those who have access to ICTs and those who continue to remain disadvantaged due to technological illiteracy; and
   - equip students with technological skills, which will enable them to participate in the knowledge economy of the 21st century (Hardman, 2004:7-8).
3. Whilst I recognize the problems associated with the use of racial categories, it must be noted that these categories still function, however unwelcome, as descriptors in the South African context.
4. Whilst there is some debate regarding the notion of scientific concepts (see, for example, Karpov, 2003) I use this term in the Vygotskian sense to refer to those abstract concepts that are imposed in the structured environment of the school classroom.

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**Joanne Hardman** is Lecturer in the Department of Educational Psychology at the School of Education, University of Cape Town. Her research interests are using Sociocultural and Activity Theory as a framework for understanding learning and cognition, tracking the development of mathematical concepts in children, computer assisted learning and teaching, provoking change in class-rooms, and developing wireless technology as a learning/teaching tool.