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Research Paper

Have teachers' perceptions regarding the pedagogical change in grade 6 mathematics lessons with ICTs altered over a 16-year period? A cultural-historical activity theory analysis

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Abstract. This paper presents data from 4 teachers across 2 non-fee-paying schools in the Western Cape province of South Africa in relation to pedagogical transformation in mathematics lessons with Information Communication Technologies (ICTs). The paper is informed by the continuing lag in mathematics and science results recorded in South Africa post-apartheid. In order to address underperformance in these core 21st-century competencies, the government introduced Information Communication Tools (ICTs) into schools to improve students' outcomes at the turn of the 21st century. However, research indicates that it is not the tool itself that leads to pedagogical change but, rather, how that tool is mobilized by teachers (Webb and Cox, 2004). Research is also clear that it is teachers' perceptions of, and attitudes to novel technology that informs how they use this in their lessons. A cultural-historical framework (CHAT) is used to analyse teachers' interview data in order to investigate: 1) whether teachers in 2019 feel that their pedagogical practices alter when using ICTs, and 2) if so, in what way these practices alter? and 3) whether teachers' perceptions of the pedagogical impact of ICTs has altered over 16 years. Findings indicate that there are differences between face to face and computer-based lessons across time, with computer-based lessons moving from being about reinforcement in 2003 to teaching/learning spaces in 2019.

Keywords: Cultural-historical activity theory, teachers' perceptions, pedagogical change.

INTRODUCTION

The context: Curriculum transitions and pedagogical change in South Africa

In 1994, South Africa emerged as a democracy against the background of nearly 50 years of apartheid rule. Under apartheid, the curriculum was firmly State controlled, and resources were differentially allotted across race groups, with white children receiving more human and material resources in schools than children of colour. The fundamental pedagogics that underpinned apartheid education sought to privilege white students and reproduce social inequality amongst children of colour. The teacher was seen as having strict control over the students as well as the pacing and sequencing of the curriculum. This model of pedagogy is often referred to as a 'teacher-centred' approach as the teacher contained the knowledge that they would then 'transfer' to the 'empty vessels' - the students. Post-apartheid, one of the first areas of change the government looked towards was to alter a curriculum of entrenched inequalities that perpetuated social inequality in South Africa. This led to the establishment of Curriculum

2005 (C2005), which was premised on admirable ideals such as a non-sexist and non-racialized curriculum that would include all students within it (Harley and Vedekind, 2004; Hoadley, 2018).

C2005 was a pendulum swing from the heavily prescribed and teacher-control over sequencing and pacing under apartheid to an outcomes-based curriculum (OBE) emphasizing student outcomes obtained through formative rather than summative assessment. However well-intentioned C2005 was, it inevitably failed as it did not meet the needs of those disadvantaged schools it sought to help (Smit, 2001; Harley and Vedekind, 2004; Hoadley, 2018; Jansen, 1998). Disadvantaged schools simply did not have the resources to implement a very complex curriculum. Moreover, many teachers at these schools lacked the requisite foundational understandings of their subjects to implement the curriculum in the absence of strongly prescribed content (Smit, 2001). In effect, rather than minimizing the gap between advantaged and disadvantaged schools, C2005 widened the gap.

Furthermore, it was unclear in the policy documents exactly what learner-centred pedagogy should look like. If learner-centred pedagogy can mean anything, it must have a developmental component; that is, it must lead to cognitive development. This implies a very sophisticated pedagogy where a teacher can intervene for developmental purposes with each child. Based on the understanding that a child is an active cognizing agent who strives to construct knowledge through transacting with the world, this view of pedagogy is often referred to as constructivist as it draws quite heavily on Piaget's (1976) cognitive constructivism. Where teachers have insufficient training to accomplish this, they revert to past pedagogical practices because they are unable to relinquish the control required to allow students to learn at their own pace. There is a body of evidence in South Africa suggesting that not only do many teachers not understand the foundations of learner-centred teaching, they also lack subject content knowledge (Spaull, 2013).

Given the failings indicated above, C2005 was reviewed to produce the Revised National Curriculum Status (RNCS) which became policy in 2002. This revision was presented as a refinement of C2005, rather than a replacement of it. Due to continued problems with implementing the RNCS at the level of schools, this was revised again in 2010 and resulted in the Curriculum Assessment Policy Statement (CAPS) (DoE, 2000; DoE, 2009). This curriculum represents an instance of the evolving policy framework in South African education within which classroom teaching and learning take place. This is because CAPS promote and develops a more inclusive education approach to teaching and learning. As stated by The National Curriculum Statement (NCS) Grades R-12, CAPS serves the purposes of: "equipping learners, irrespective of their socio-economic background, race, gender, physical ability, or intellectual ability, with the knowledge, skills and values necessary for self-fulfilment, and meaningful participation in society as citizens of a free country" (CAPS, 2012:4). It is, therefore, aimed at the level of the curriculum but not at the level of pedagogy; the focus on learner-centeredness in pedagogical practices still underpins the curriculum (Du Plessis, 2012). Under the NCS, there is still a commitment to learner centred education, but the content is more prescribed and subjects more delineated than under C2005. However, CAPS is not without its challenges. While teachers have welcomed the new curriculum, they express a need for further training, express dis-ease at the curriculum's workload as well as requesting more resources to implement CAPS (Moodley, 2013). While the changes and revisions to the curriculum sought to better students' outcomes through a more inclusive and equitable education system, South Africa continues to perform extremely poorly in international benchmarking tests, especially in mathematics and science. This is particularly problematic when one considers that South Africa spends over 6% of its GDP on education.

In order to meet the challenge of underperformance, the government has turned to technology as a tool that could potentially impact positively on student attainment. In 2004, the white paper on e-learning was presented, advocating for full ICT integration and connectivity in South Africa by 2013 (DBE, 2004). However, the data from Table 1 revealed that there was a significant lack of facilities in many of the disadvantaged areas.

If only 23% of schools in South Africa have a computer laboratory, this calls into question how effective any e-learning initiative can be in disrupting the historical patterns of underperformance we currently are faced with. Moreover, the introduction of C2005 has led to additional pressure being put on teachers to cover a content heavy curriculum. For this reason, we decided to analyse teachers' perceptions of computers before C2005 and then after its introduction. We decided that a 16-year gap in the interviews would allow for 1) teachers to become more familiar with technology and 2) teachers to become familiar with C2005. We hypothesized that growing familiarity with technology coupled with a new curriculum, would alter teachers' perceptions of teaching with technology. Our rationale for this study is two-fold: on the one hand, we want to see if teachers' perceptions alter over time and how this impacts on how they perceive teaching with technology. Research is clear that teachers' perceptions impact on their enactment of the curriculum, hence our focus on perceptions. On the other hand, we have an interest in understanding what pedagogy looks like in technology rich classrooms according to teachers. In their opinion, does pedagogy differ and if so, in which ways does it do this? There is a dearth of published case studies that track change in perceptions over time, and it is this gap that the paper seeks to address using a framework (CHAT) that is

Table 1. Computer centres across provinces in South Africa.

Province	No. of schools	With computer lab	%
Eastern cape	5676	596	11
Gauteng	2031	1529	75
Free State	1615	353	22
KwaZulu Natal	5931	992	17
Limpopo	3923	426	11
Mpumalanga	1868	290	16
North West	1674	371	22
Northern Cape	611	313	51
Western Cape	1464	886	61
Total	24793	5756	23

NEIMS (2011: 24)

capable of tracking change through a dynamic systems approach. It is against this historical background that the current study asks the question:

1. Do teachers in 2019 feel that their pedagogical practices alter when using ICTs and if so,
2. In what way do these practices alter?
3. Is there a difference between teachers' perceptions of ICTs to teach mathematics in grade 6 from 2003 to 2019?

Teaching and learning with technology in mathematics: Towards attainment?

The logical question to ask now is whether ICTs have been proven to lead to better attainment in mathematics at a primary school level; this is, after all, the South African government's hope when rolling out ICTs. There is a large body of research to indicate that ICTs can indeed impact positively on student attainment especially at primary school, but this is dependent on how they are used (Tamim *et al*., 2011; Higgins *et al*., 2012; Li and Ma, 2010; Cheung and Slavin, 2013; Demir and Basol, 2014; Xie *et al*., 2018, Chauhan, 2017; Slavin *et al*., 2009; Slavin and Lake, 2009; Rakes *et al*., 2010). Indeed, there has been a change from 2002 to 2018 in children's attainment at school with 88% of all children aged 10 to 11 having completed grade 3, up 78% from 2002 and 70% of children aged 16-17 having completed grade 9 in 2018. This is an increase in 20 percentage points over the 16-year period. We do not claim that it is the use of ICT's alone that has impacted on this performance, however, the rise in attainment is of interest given that ICTs have been introduced during this period. Moreover, research indicates that student attainment in mathematics in elementary school is significantly impacted where a constructivist pedagogy underpins the use of ICTs (Tammin *et al*., 2011). Exactly what 'constructivism' means, however, is not entirely clear. In its most cogent formulation, constructivism must require a more skilled person, guiding a less skilled novice into certain ways of knowing and being. This process is discussed later in the paper when we outline the theoretical framework for this study. In its least coherent form, constructivism has come to mean that a child, alone, constructs knowledge and a teacher merely guides the child, deciding the pace and sequence at which they 'discover' novel knowledge. On this understanding, a child will construct knowledge about their world without assistance, or with minimal assistance. Karpov (2005) has indicated the problems of this type of view by illustrating that left to their own devices, children will construct empirical knowledge but not the theoretical knowledge that characterises school-based teaching and learning. Consequently, a child may be trapped by surface, empirical traits rather than the deeper theoretical understanding underpinning these traits. Understanding exactly what a constructivist pedagogy requires, therefore, requires a theoretical foundation for elaborating it.

Theoretical underpinnings

This paper is based on the theoretical foundations first articulated in the 20th century by Vygotsky (1978, 1986). While he would not have called himself a constructivist, there is much in his pedagogical approach that adds depth to this term and enables us to operationalize it in actual classrooms. Central to this pedagogical view is the fact that teaching and learning are dialectically entailed and that mediation by a culturally more competent 'other' is necessary for development. Contrary to Piaget (1976) who claimed that development led to learning, Vygotsky's work argued that learning can lead to cognitive development. This viewpoint places the teacher, or culturally more competent other, at the centre of learning. Through mediation, guided assistance, the teacher leads the student from a place of not knowing to a place of acquiring knowledge in a unique pedagogical space called the Zone of Proximal Development (Vygotsky,1986,

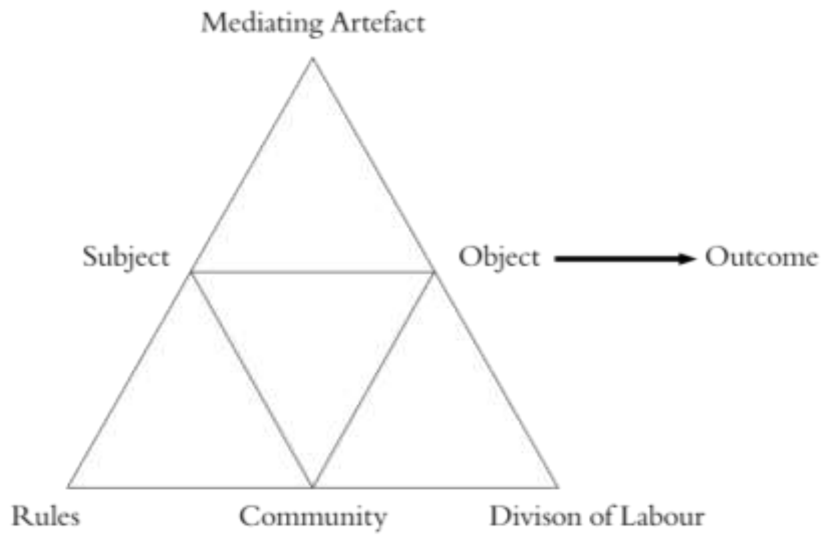

Figure 1. An activity system. (Source: Engeström, 1987:75).

1986, 1978). It is important to note that this zone is developmental; that is, it is not linked to a single specific task or activity, but rather linked to development over time. It is in this way that mediation differs from the Western notion of scaffolding, which is task/activity dependent and does not necessarily have a developmental outcome (Wood *et al*., 1976). Core to the motion of mediation is the understanding of what the child learns through this process. Vygotsky distinguished between every day or spontaneous concepts and scientific or abstract concepts. While everyday concepts are learnt by the child without much instruction, scientific concepts are so abstract that they need to be actively taught to the child. These are the concepts that provide the child with the psychological tools to understand reality deeply. While distinct, every day and abstract concepts are dialectically entailed: one understands the abstract in relation to the everyday and the everyday becomes conscious in relation to the abstraction being taught. What we can see here is the absolutely central role that the teacher, or culturally more competent other, inhabits. This is not a guide on the side. This is the person who is responsible for moving development forward.

While Vygotsky's work underpins the pedagogical foundation of this paper, he did not articulate the social world and its interplay with the developing individual in enough depth for his theory to illustrate how the social becomes individual; or rather, how the mind is social. This step is taken by Engestrom (1987) who draws on the work of Vygotsky and Leontiev (1981) to develop a view of human activity as a germ cell for analysis. Cultural-Historical Activity Theory (CHAT) was developed by Engestrom in conjunction with Cole (1996). For them, "psychological processes emerge through culturally mediated, historically developing, practical activity" (1996: 108). One cannot focus solely on the level of the individual when studying humans, one must focus on the activity systems in which actions are carried out to solve goals and are driven by the motive that animates the activity (Nardi, 1996; Kuutti, 1996; Lim, 2001; Lim and Hang, 2003; Lim and Chai, 2004). Importantly for this paper, CHAT can study how a novel tool, such as technology, can impact an activity system.

The basic unit of analysis for CHAT is an activity system as illustrated in Figure 1.

What we see above is that a subject, in our case a teacher, acts with the use of tools (ICTs) on the object of an activity (in this paper, one presumes the motive is to get students to understand mathematics) in order to arrive at an outcome (mathematically proficient students). This plays out within a context in which rules prescribe actions and where division of labour mediates between the community and the object. The community, in this instance, consists of those people who share the common object. It is important to note that no activity system operates in isolation; Figure 1 is merely attempting to freeze the activity system in order to illustrate its key components. It is these components that informed the development of the interview protocol developed for teachers in this paper. A further interesting methodological tool provided by CHAT is the notion of contradictions or double binds that emerge both within and between activity systems (Engestrom, 1987). These contradictions are sites of dynamic change, whether progressive or regressive.

Teacher's perceptions of teaching elementary mathematics with technology

There is a body of knowledge indicating that attitudes and perceptions impact on behaviour (Zimbardo *et al*., cited by

Asiri *et al*., 2012; Domingo and Gargante, 2016). Teachers perceptions of ICT usage in their classrooms is also fairly well documented, with teachers generally responding favourably to the use of ICTs to teach mathematics especially (Karasavvidis, 2009; Blin and Munro, 2008; Hutchinson and Reinking, 2011; Badia *et al*., 2014). There is however, a dearth of findings regarding exactly how teachers think their pedagogy alters when they use ICTs. It is this gap that the current paper addresses. What findings we do have, indicate that teachers use technology to enhance rather than transform their pedagogical practices, often using it to reinforce what has already been taught and not as a novel tool for development (Conlon, 2004; Smeets, 2005; Cubukcuoglu, 2015; Zhao and Cziko, 2001; Author, 2015; Mwendwa, 2017). Added to this is the finding that teachers feel underprepared to teach using technology which can have a negative impact on their attitudes and perceptions of technology use (Condie and Munro, 2007, 1999; Karasavvidis, 2009). Our study aimed to investigate whether teachers' perceptions to using technology to develop mathematical understanding changed over a 16 year period. The rationale underpinning this was that teachers' perceptions impact on their pedagogical practices; hence, positive perceptions to working with ICTs could, we argue, translate into positive pedagogical practices with technology in a classroom.

METHODOLOGY

This study adopts a qualitative approach to data analysis as it seeks to understand patterns of change in perceptions rather than to generate statistical models for intervention. We adopted a case-study design in order to study pedagogical perceptions in depth. The study was carried out in two parts; in 2003 thirteen teachers were interviewed regarding their perceptions of pedagogical change in mathematics with ICTs. Schools were selected based on the following criteria:

1. They were disadvantaged in terms of having low socio-economic status and restricted human and material resources.
2. They were part of the Khanya Initiative that introduced ICTs into the schools.
3. They were well-functioning, where this refers to the school running to a timetable; having a management structure and principal and where attendance by teachers was high.

We selected 8 schools and all mathematics teachers in these schools volunteered to take part in the study. This was just at the time that the government had launched a campaign to equip disadvantaged schools with computers under the Khanya initiative. This initiative introduced by the Western Cape Department of Education, aimed to deliver ICTs to underprivileged schools to impact positively on both students' performance as well as providing teachers with access to up to date knowledge. In 2019, I attempted to contact these 13 teachers to re-interview them. I was able to contact 8 of the teachers who were still teaching, but only 4 of the teachers ultimately took part in this interview. That is, the same cohort that was interviewed in 2003 was re-interviewed in 2019. The same interview schedule was used on both occasions. The demographic data for the teachers is outlined in Table 2. This data is drawn from 2019.

The school context- non-fee-paying schools

Four teachers from two separate non-fee-paying schools took part in this study (Table 3). In terms of section 21, non-fee-paying schools are disadvantaged schools that are entirely funded by the government and therefore do not charge school fees. Schools in South Africa are classified into quintiles from most to least poor. While a quintile 1 school caters to the poorest 20% of all schools, a quintile 5 is the least poor and more likely to be urban and a former Model C school (schools that were for white children only under apartheid and were, therefore, very well resourced). The government allots money to schools depending on their quintile, with quintile 1 receiving the most funding and quintile 5 the least.

Data gathering, ethics and procedures

Interviews of between 45 min and 1 h and 15 min were collected over a period of 4 weeks. The interviews were recorded using a voice recorder and were transcribed by author 1 directly after the interview. Ethical approval was given by both the Western Cape Department of Education as well as the university where both authors work. Participants were asked to give consent to have their interviews recorded for research purposes and all names were disguised so as not to identify any specific teacher. Data were stored on a secure server.

Analysis

Categories from CHAT were used to design both the interview schedule as well as to analyse the data collected from the interviews. These categories are: subject (usually the teacher); tools (what mediating artefacts are used in teaching mathematics); rules (what rules constrain and afford behavior); division of labour (who does what and who holds the power in the lesson); the object (what is the problem space being worked on in the activity) and finally, the outcome (what is produced

Table 2. Primary school teacher demographic data.

Demographic details	Teacher 1	Teacher 2	Teacher 3	Teacher 4
Gender	Female	Male	Male	Female
Age	63	43	42	60
First language	Xhosa	Xhosa	Xhosa	Afrikaans
Qualifications	Honours in Education	Senior Diploma specializing in Science and Technology	PGCE	PD and NPDE
Years of teaching experience	37	24	18	38
ICT Training	Yes	Yes	Self-taught	Yes
2003 ICT competence	CAMI Maths	CAMI Maths Computer	CAMI Maths Computer	CAMI Maths Computer
2019 ICT competence	CAMI Maths Edmodo YouTube Greenshoots	CAMI Maths Edmodo YouTube Internet PowerPoint Greenshoots	CAMI Maths Tablets YouTube Internet PowerPoint Greenshoots	CAMI Maths Smartboard Tablets Computer Internet Projector
Tools used before ICT	Board Textbook 'Concrete things' e.g. pictures/ scales	Board Textbook	Board Textbook	Board Textbook

Table 3. The schools.

School	Teacher	Quintile	Number of students	Number of teachers	Average class size
Luhlaza Primary	1, 2, & 3	1	1250	31	41
De Hoop primary	4	2	1629	37	45

from the activity). Interviews from 2003 were analysed in 2003 and interviews from 2019 were analysed in 2019. The different activity systems derived from the interviews over time were then compared for 1) contradictions, 2) differences across time and 3) differences between face to face and ICT based pedagogy in mathematics lessons. Author 1 and a research assistant coded the data using the CHAT codes. Inter-rater reliability was 89%.

FINDINGS AND DISCUSSION

In the following section of analysis and discussion we address the three questions posed at the beginning of this paper viz.:

1. Do teachers in 2019 feel that their pedagogical practices alter when using ICTs and if so,
2. In what way do these practices alter?
3. Is there a difference between teachers' perceptions of ICTs to teach mathematics in grade 6 from 2003 to 2019?

In 2003, the government had only recently rolled computers out into schools under the Khanya project that equipped disadvantaged schools with computer laboratories and software, most notably for mathematics, CAMI maths. Teachers reported receiving very little training in either how to technically use a computer or how to navigate software: "*I can say, uh, we had, I had one hour. Yes, one-hour training. And I never seen this. I don't have a computer [at home]" (Teacher 1, 2003).*

Author 1 (2008) has analysed CAMI Maths as a teaching/ learning programme before and does not intend to rehearse the arguments here, rather we merely point out that CAMI maths is a drill and practice software package. We restate that there is nothing wrong with drill and practice software if the object of the lesson is to reinforce concepts already learnt in class. However, if the computer software is being used to introduce new concepts, then drill and practice software (premised on behaviourist notions of learning as stimulus-response), is unable to deepen mathematical concept knowledge. Below we begin to develop a picture of the activity system of the mathematics classroom in 2003 according to teachers' perceptions of ICTs as teaching/ learning tools at that time in order to address the question of whether teachers' perceptions of pedagogy with technology has changed over time and, if so in what ways it has.

Activity systems of face to face mathematics lessons: 2003

Subject

Interestingly, but not surprisingly, teachers indicated that they believed children learnt actively and that they tailored their lessons accordingly. This is explained by Teacher 4 below:

Extract 1: Teachers' beliefs of how children learn in 2003 in face to face lessons

> **Teacher 4:** I know that children learn by doing stuff…Right let's take for example, um, times table how do we do it. Right we gonna count in twos so you use your whole body standing up two four six eight ten [demonstrates movements with his hands] **…**and then [to consolidate learning] he's got to do an exercise with his friend they got to work something else out, how can they come, but as they playing they also learning from each other.

Teacher 2's beliefs about how children learn to echo those of Teacher 4: *"I think for me…children learn something by actually doing it practically… and in a group. I can say, groupwork (2003).*

It is not surprising given that C2005 had recently been rolled out that teachers were using the language of the curriculum document which focused on children as active cognizing agents. In the above extracts, they emphasize the learner and the need for practical demonstrations. We have a picture then of the subject position, the teacher, explaining that children learn actively and that learning should, be done in groups.

Object

The object is the motive for the activity. During the activity, the object is worked on and transformed into an outcome. All teachers in 2003 indicated that the object of face to face mathematics lessons in Grade 6 was deepening students' understanding of mathematics. So, for Teacher 2: "*In the classroom that's where I do the teaching, you know, the expositions of concepts"* (interview 7 April 2003).

Division of labour

The roles in the face to face lesson are very clear; power inheres in the teacher who is responsible for teaching and students are generally passive recipients of the teachers' knowledge. So, for example Teacher 1 indicates: *"no, you see, I am in charge. So no, they not going to talk. They can put their hand [up] but I say what they must do".*

Community

The community of the face-to-face lesson is restricted to the teachers and the students as teachers report that parents seldom engage in assisting with mathematics lessons. Teacher 4: *"the parents here, I can say, they don't help. They don't even help with the homework so I can say no. they don't help in the classroom."*

Rules

Pacing and sequencing in the classroom are firmly controlled by the teacher. The teacher asks questions to which students respond. Teacher 2 indicates that "*they must work together. It is…uh…I choose the task and they must all work together. Then I tell them when to move on".*

Tools

Teachers in this study use the blackboard, language and textbooks as mediating artefacts. We can graphically represent the face to face mathematics lessons as an activity system as in Figure 2.

Activity system of computer-based mathematics lesson: 2003

Subject

While still indicating that children learn actively, all teachers indicated that they had to control student interaction with the computers. For Teacher 4: *"they must copy my actions on the computer, exactly, exactly"* (2003). This paints a picture of students as imitators of

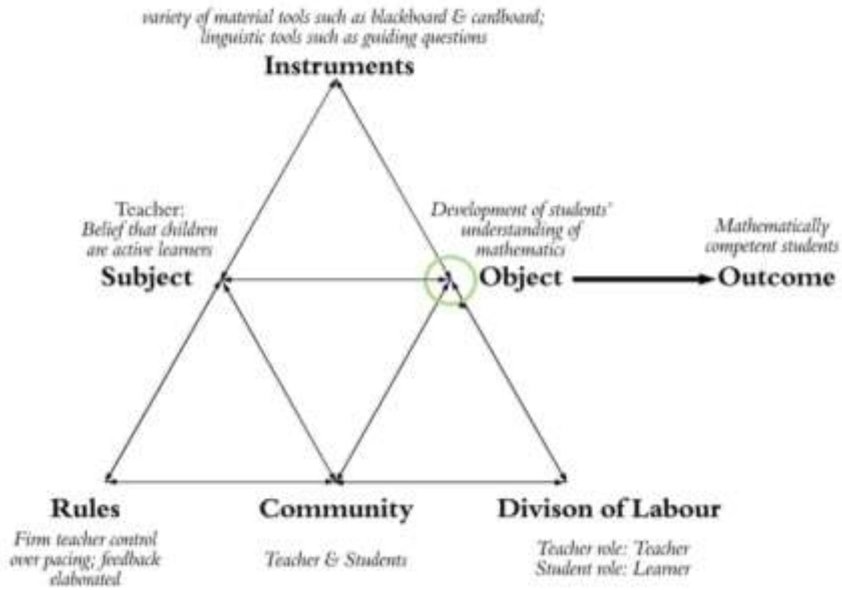

Figure 2. Traditional face to face teaching.

Table 4. Conflicting views of computer use.

Expressed View	Teaching computer use	Reinforcing Mathematics from class
Teacher 4	I spend most of the lesson … telling the learners what to do, where to click their mouse, those sorts of things. Very basic things. It can be frustrating. (5 April 2003)	“if we talk about learning right, it’s [the computer] a nice skill that they can use, but um, learning, I think we are still in the beginning stages and I don’t feel that it’s that effective in the learning process this far” (5 April, 2003)
Teacher 3	In the computer lab that’s where they get to practice and learn new skills … I can’t say that the computer is developing their mathematics…… [using the computer] is the expected thing to do in this atmosphere of this IT technology thing.	It’s very good for practising what they learn in class. Very good.
Teacher 2		What we do in class, then they practice it in the computer room’

the teacher, rather than as active cognising agents constructing their knowledge.

Object

All teachers felt that the computer-based lessons were not focused on learning mathematics but either on A) teaching the children how to use the computer or B) using drill and practice software to reinforce what was taught in class. These different views of teachers can be summarised in Table 4.

These two views position two different objects and therefore, two activity systems in the computer-based lesson. Author 1 (2008) has called the first activity system, where the object is reinforcing knowledge already learnt, reinforcement pedagogy and the second system, where the computer is the actual object, directive pedagogy, as the motive for the activity lies in directing students’ actions in relation to the novel technology.

Division of labour

This refers to ‘who does what’ in the lesson. The teachers all expressed concern that they were not sufficiently trained to use computers, leading them to become very directive and controlling in the computer lab so that students would not think they were “stupid”. Three of the teachers indicated that they took on more of a facilitator

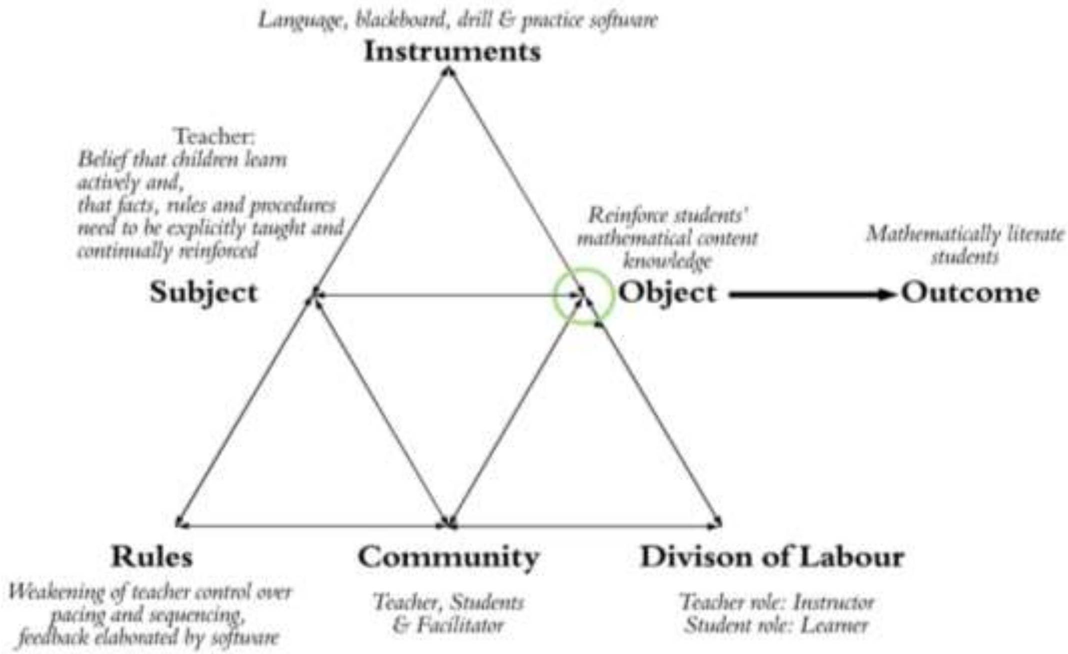

Figure 3. Reinforcement pedagogy.

role in the computer laboratory, while also indicating that students sometimes became peer-teachers.

> **Teacher 1:** teachers …are afraid because they don't know this thing they afraid to break it because this is a lot of money now, we been told that [laugh] and uh, then they seeing that they're teachers and then how is a teacher supposed to be stupid now? And then this is now a new thing. So I don't know how, how, how it works, and I think maybe that's something that, a paradigm shift that must take place in the teachers first

Rules

According to the teachers, there is more room to slow pacing and sequencing in the computer-based lessons and the feedback given by the computer is elaborated for the students, giving them more control over their learning. This is outlined by Teacher 4 below:

> **Teacher 4:** … it's a freer lesson [the computer lesson]. They are in charge of their own learning and I find that they help each other out quite a bit as well. And I sometimes will let them play a game. I mean things like that create enthusiasm.

Tools

The computer is not actually viewed as a teaching-learning tool, but rather, as the object of the computer-based lesson. For example, you have Teacher 1 indicating that '*we have to teach them the computer, basic things, like, uhm, like click on this and what is the mouse'.* However, a second activity system, as defined by a different object, was also indicated where the object of the lesson is to reinforce what was covered in the face to face lessons.

Community

The community of the computer-based mathematics lesson is larger than that of the classroom as it contains a facilitator who helps with technological issues.

We can graphically represent the activity systems of the computer-based lessons as in Figures 3 and 4.

In summary, what we see in 2003 is that there are distinct differences between the computer-based activity systems and the face-to face-systems. What we can see is that pedagogy in the face to face lesson in 2003 is motivated by developing students' mathematical understanding while in the computer lessons, pedagogy is motivated by the need to reinforce knowledge and develop computer skills.

Activity systems of face to face mathematics lessons: 2019

We turn now to the interview data from 2019 to establish if teachers' perceptions of teaching with ICTs has changed over the years as they have gained more

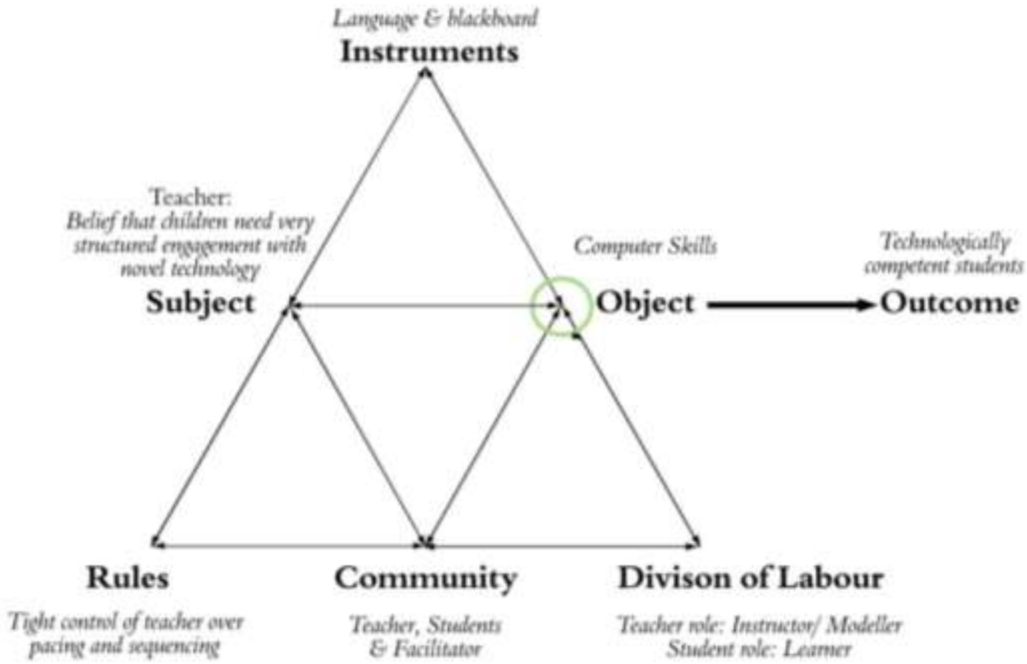

Figure 4. Directive pedagogy.

experience with the tool. One of the clear messages from 2003 was that teachers had insufficient training in ICTs as teaching/learning tools and were only using them because "*We were told to use them. They told us, no, you must use them"* (Teacher 1, interview 3 April 7, 2003). Further, in 2003, C2005 had recently been rolled out and teachers were coming to grips with having to develop pedagogy that aimed at learner-centred teaching. In 2019, C2005 had been through two revisions and CAPS was now guiding teachers' pedagogical practices. While still learner-centred, CAPS prescribe content that must be covered, and teachers are under an increased workload in order to cover the curriculum (see The Context above).

Face to face mathematics lessons 2019

Subject

In 2019, all teachers still indicate that children learn actively. This is unsurprising given the learner-centred approach to pedagogy advanced by CAPS.

> **Teacher 1:** They learn more, they learn more when they see things than when you tell them, and when they are busy, then they learn more.
>
> **Teacher 4:** I think, I think, um, I think they learn in different ways. Um, some is by doing and obviously some by seeing and by being actively, actively involved in the, in the learning

Object

The object of the face-to-face lesson remains developing students' mathematical understanding. However, there is an inherent contradiction that now emerges in the object, between curriculum coverage and developing understanding. Faced with the pressure to complete the prescribed curriculum in time, teachers indicate that they do not have enough time to develop mathematical understanding.

> **Teacher 2:** we try to get them to understand, but there is so much work to cover. Sometimes, you know, that slow one, I can't slow down for him.
> **Teacher 4:** I think, I think, um, I think you trying to get them to know this maths but then you also have to finish the curriculum. I think CAPS is too much for us.
> **Teacher 3:** they have to cover [the curriculum] they must pass the tests. It's not easy for us.

Rules

Pacing and sequencing is still controlled by the teachers

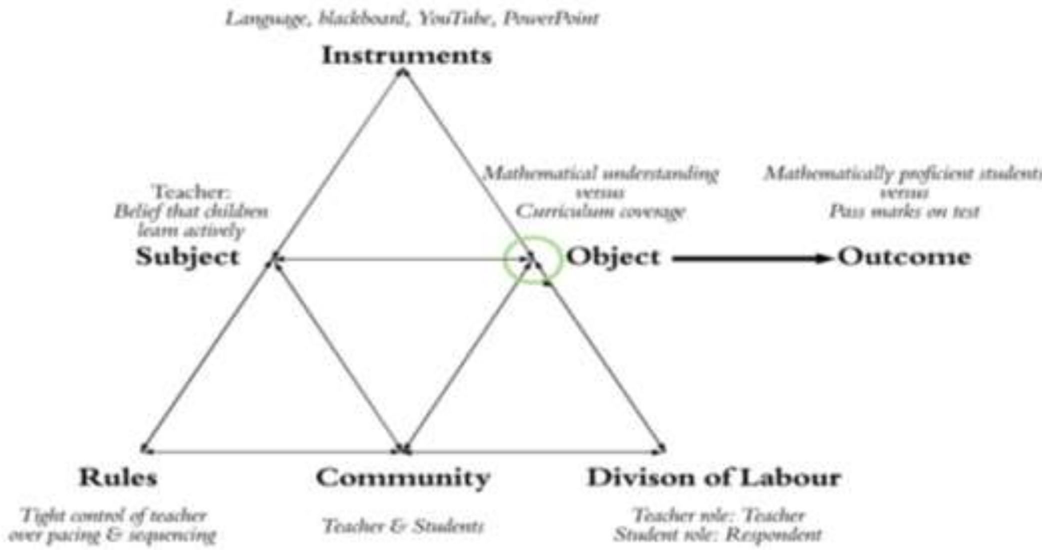

Figure 5. Activity system of face to face mathematics lesson 2019: Traditional pedagogy.

in the class; in fact, it appears there is more control exercised by the teachers due to the need to cover the curriculum. Teacher 4 indicates *"CAPS is a lot to cover. So many assessments so we have to keep up. Sometimes you are even teaching just to get to the test".*

Tools

Somewhat interestingly, teachers indicated that they now use technology, such as YouTube videos and PowerPoint slides to teach in face-to-face mathematics lessons. They find that the graphic representations offered by the technology are useful in motivating students to focus on the lesson.

> **Teacher 1:** I use YouTube now. Sometimes you can show them things, like, uhm, I used this game on fractions I found. It was very nice. The children liked it.

Division of labour

In the face-to-face lessons, the teacher exercises control over what is taught and there is a strong delineation in roles with teachers teaching and students listening and responding to questions.

Community

As in 2003, the community comprises just the teacher and the students. If we graphically represent the face to face lesson in 2019 as an activity system, we can see as in Figure 5.

What Figure 5 illustrates is that the activity system is similar to 2003 (see Figure 2). Yet, contradictions have arisen in the system and novel tools have been mobilised to teach mathematics in face-to-face lessons. The contradictions evident in the object and outcome of the system highlight spaces of dynamic change. Teachers indicate that they must cover the curriculum even at the expense of deepening students' mathematical understanding. The object, then, becomes not the learning of mathematics but rather, the coverage of the curriculum.

Activity systems of computer-based mathematics lessons: 2019

Teachers have had 16 years to familiarize themselves with the novel technology that has been rolled out into schools. We may, therefore, expect to see some changes in how they perceive teaching/learning with ICTs.

Computer-based mathematics lessons 2019

Subject

As with the face to face lessons, teachers all indicated that children learnt actively through interacting with problem-solving in real-world scenarios. Of interest is the fact that teachers now felt that the ICTs could help children to do that better than it could be done face-to-face.

> **Teacher 4:** So definitely active, they must be active. And they must have that interest. That's why I use YouTube. You

know these kids here, they never seen the sea! Ja, Really. So I can show them that on YouTube and I can do these fun things and show them that look, now, maths is fun.

Object

In 2003, the teachers had indicated that the computer itself was the object of pedagogy. By 2019, this has changed completely as teachers now saw computer hardware and software as a tool for deepening mathematical understanding in an enjoyable manner.

Teacher 1: Exact, mmm, they learn together. So the one can help the other just like that. And that's making them to learn maths better.
Teacher 2: Collaboration, um, I think so. So in the face to face lesson, it's just me talking. They get bored just teacher talks, talks, talks. But in the computer lab they can find their own knowledge.
Teacher 3: But then between the teacher and the learners, surely it would bring that collaboration. Because I have to go and assist the learners if they can't understand what like I was showing. Or pause the video maybe if they don't understand like what is the video about. Unless I've been pausing, explain the video, what is it about, yes.

Rules

Pacing and sequencing are relaxed in the ICT lessons and children can work at their own pace to cover the work being done. For teacher 3 *"in the lab, they can move at their own pace. Ja. I think it's more learner centred because they can choose, look, I need to do this or I must move on. I think it's good that way".*

Tools

Teachers use a variety of novel ICTs, such as computers, smartboards, tablets and PowerPoint. They also use the internet to view YouTube.

Division of labour

Division of labour in the computer laboratory:

Teacher 1: [the teacher's role] …Is to facilitate then you are not, it's more the, the technology is more centred. The learners are the ones that, they, they, they grasp the learning on their own than you telling them. Yes, they do differ, cos as I've said, the other one is more learner centred than the other one is teachers and you do the talking too much, but in the ICT no talking, just communicate, and they, they collaborate within themselves.
Teacher 3: Yes, it is quite different, because what I find is that it's also something for them new. It's exciting. And they really want to dwell, like just jump into it and do it. …. So, so they learn without me having to reinforce, um, what I'm teaching.
Teacher 4: They (the roles) differ because, for example, if we're talking about face-to-face lessons, that means like a teacher like in front of the learners. And not face-to-face means like a class without a teacher, like let's say maybe learners they're on, on their own computers, and then the teacher maybe is in another room like using the computer. The roles will differ, yes.

Community

The community in the computer-based mathematics lesson is the students and the teacher.

The data indicate that pedagogical practices in 2019 differ between face-to-face lessons and computer-based lessons, with computer-based tasks taking on a more mediating role and developing understanding (Figure 6). For these teachers, face-to-face lessons have become, by 2019, a means to 'teach to the test' and cover the curriculum, often at the expense of deepening mathematical understanding. We now turn to investigate whether pedagogy has altered over the 16 years in relation to teaching mathematics with computers

If we compare the face-to-face activity systems from 2003 with 2019, we see that contradictions have begun to emerge in the system, due to the curriculum content that must be covered because of CAPS requirements. This leads to teachers in 2019 indicating that they are often unable to deepen mathematical understanding as students are required to cover the curriculum and pass tests. The outcome of the system, then, becomes passing a test, rather than developing mathematically literate students. This is a possible explanation for why students continue to under-perform on international benchmarking tests of mathematics and science such as the TIMSS tests and calls into question the efficacy of the current CAPS.

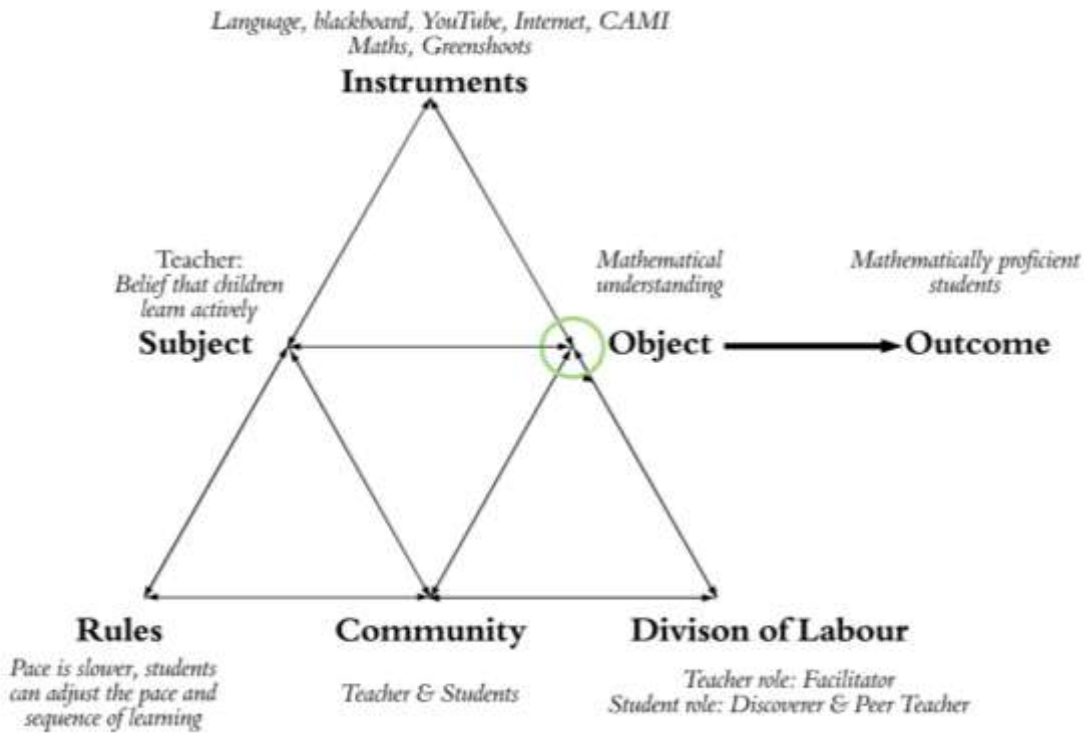

Figure 6. Activity system of computer-based mathematics lesson 2019: Collaborative pedagogy.

The data indicate a change over time in the computer-based activity systems from 2003 to 2019. In 2003, the computer itself was the object of the mathematics lesson whereas in 2019, we see a shift towards the computer becoming a mediating tool, capable of acting on developing students' mathematical understanding. Considering the narrowing of the object in face-to-face lessons in 2019, the ability of the computer to act as a cognitive tool to develop mathematical understanding is of interest. Practically what this suggests to us is that ICTs can be used to develop students' mathematical understanding. However, a brief caveat is in order; this is a case study that does not seek to generalise to the greater population and we recommend further research to 1) ascertain the prevalence of this finding and 2) to move fully study the relationship between the use of ICTs and mathematical outcomes in the South African context.

CONCLUSION

This paper set out to examine the extent to which teachers' perceptions of whether their pedagogy varies in face-to-face versus computer-based lessons over time. Findings indicate that in 2003, when computers had been recently placed in schools, teachers perceived these not as tools for cognitive development but rather as the object of the activity or as a mechanism for reinforcing what had been covered in class. The face-to-face lessons in 2003 were characterized by a focus on developing mathematical understanding using traditional tools such as language and the chalkboard. In 2019, after the advent of CAPS, we see a distinct change in how teachers perceive learning with computers. The face-to-face lesson becomes a space in which a contradiction emerges in the object of the activity between curriculum coverage and mathematical understanding with teachers eager to teach to meet assessment standards.

Conversely, the computer-based lessons now become spaces where the computer hardware and software acts as a cognitive tool mediating mathematical understanding. The roles have now shifted, with the teacher guiding interaction and students often acting as peer teachers. A brief caveat is in order; while research has established that teachers' attitudes and beliefs inform their pedagogy, it is important to note that there is often a disjuncture between what teachers 'say they do' in the class versus what 'they actually do' in the class. Further observational data would add to our understanding of teaching with technology in no fee-paying schools.

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