Researching pedagogy: an Activity Theory approach

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Abstract

Activity Theory (AT), arising from the work of the Soviet psychologist, Vygotsky and his colleagues, has presented scholars who are interested in child development with a fecund theoretical basis with which to understand how socio-cultural factors impact on developmental trajectories. The strength of this approach to studying teacher/student interactions in classrooms is found in its ability to situate general developmental principles in time and place. A current version of this theory developed by Engeström (1987) elaborates Vygotsky's work, providing a useful heuristic for analysing activity as a collective endeavour. However, while providing a useful framework for studying human activity, Engeström's activity systems work has yet to be fully operationalised in a classroom setting. Conceptualising pedagogy as an activity system, this paper elaborates an analytical framework for studying pedagogical practices in classrooms along the AT dimensions: viz. tools, rules, object, division of labour, community and subject. The paper does this by providing an historical investigation of the roots of Engeström's work from Vygotsky's formulation of activity as triadic, through Leontiev's elaboration of this, arguing ultimately for developing Engeström's activity system's approach into a framework capable of investigating pedagogy in context. A novel analytical framework is developed that tracks pedagogy across the various AT dimensions. Empirically the paper provides an example of the use of this novel analytical framework to track pedagogical practice in a grade six mathematics lesson.

Introduction

Pedagogical activity is complex and multifaceted and definitions of what constitutes pedagogy are by no means static (Watkins and Mortimore, 1999; Webb and Cox, 2004). Derived from French and Latin variations of the original Greek, pedagogy literally means the act of an attendant leading a child to school or supervision of a child and has come to be viewed by some as the 'science' of teaching (Webb and Cox, 2004). While the former meaning is clearly obsolete in 21st century classrooms, the latter definition is potentially rhetorically hollow and appears to offer no considered definition of pedagogy as it plays out in context. In this paper pedagogy is defined as *a structured process whereby a culturally more experienced peer or teacher uses cultural* *tools to mediate or guide a novice into established, relatively stable ways of knowing and being within a particular, institutional context, in such a way that the knowledge and skills the novice acquires lead to relatively lasting changes in the novice's behaviour, that is, learning* (Hardman, 2007). This definition draws on the body of knowledge associated with Vygotsky's conceptualisation of mediation (1978) and Engeström's (1987) systems thinking. Vygotsky's conceptualisation of pedagogy as involving mediation by a more competent peer or teacher within the zone of proximal development, informs this definition's focus on teaching as involving mediation by an experienced Other. Engeström's systems thinking enables one to conceive of pedagogical practices as playing out in a rule bound context in which power and control influence practice. Drawing on this definition of pedagogy, this paper presents an attempt to theorise pedagogy using Engeström's notion of activity systems as units of analysis. This requires the development of a language of description[1] capable of being able to track pedagogy in context. The high level concepts suggested by AT, therefore, need to be brought into play with the empirical data that informs this paper. While Hedegaard (1998), Daniels (2007) and Edwards (2005) have mobilised AT concepts in their work, there is currently a dearth of methodological tools available with which to analyse pedagogy using the systems thinking arising from AT. To meet this need, this paper represents the first steps in the development of a language of description derived from AT to investigate pedagogy. It is hoped that this paper will open a methodological discussion about using AT to study pedagogy. The empirical work used to animate the framework developed here is drawn from a grade 6 mathematical classroom in a disadvantaged school in a rural area of the Western Cape Province, South Africa. In order to construct a language of description[1] with which to interrogate the data from this school, the paper traces the development of Engeström's version of AT from Vygotsky's initial project, through Leontiev's elaboration of this work.

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1 A 'language of description' refers to the development, from high level theoretical concepts, of an analytical framework with which to read the empirical data. For Bernstein (2000) "a language of description constructs what is to count as an empirical referent, how such referents relate to each other to produce a specific text and translate these referential relations into theoretical objects or potential theoretical objects". (pp.132–133)

The origins of Activity Theory: mind in society

Since Descartes' exposition of the cogito as a rational principle, psychologists and philosophers have debated the nature of knowledge; how does one come to know something and what can one know with certainty? In a bid to address this question within a Marxist psychology, the Soviet psychologist and school teacher, Vygotsky postulated that mind is socially constructed during communicative interaction between culturally knowledgeable adults and children. In the West, Vygotsky's theory has been taken up as a body of knowledge referred to as socio-cultural theory (Mercer and Kleine-Staarman, 2005; Wertsch, 1991; Cole, 1996). While Vygotsky's work privileged semiotic mediation in Russia attempts to develop Vygotsky's work have fore grounded the analysis of social transmission in activity settings, rather than focusing on semiotic mediation. The picture differs in the West however, where much of the work has tended to ignore the social beyond the interactional and to focus on individual and mediational processes at the expense of a consideration of socio-institutional, cultural and historical factors. For socio-cultural theorists the focus is on *semiotic mediation* and the developmental use of signs and symbols (especially language) (Wertsch, 1991; Mercer and Kleine-Staarman, 2005). To avoid any potential confusion in this paper, Vygotsky's work is referred to as first generation Activity Theory,[2] indicating 1) the recognition of his theory as the forerunner of and indeed the conceptual basis for later versions of Activity Theory (AT) (Leontiev, 1981; Engeström, 1987) and 2) the term 'Activity Theory' more immediately captures the notion of tool mediated object oriented activity as the basis for the development of human understanding that is the cornerstone of Vygotsky's work (Daniels, 2001). Central to an AT perspective is the understanding that learning (and hence teaching) is a culturally based social endeavour. This approach foregrounds the communicative aspects of teaching/learning in which knowledge is shared and co-constructed (Mercer and Fisher, 1997). This differs then from a view of learning that promotes a more individualist explanation of learning such as Piaget's genetic epistemology[3] (1959) or cognitive science approaches. For Vygotsky, *mediation* is the key to understanding how children learn and, consequently,

2 It should be noted, however, that Vygotsky himself did not refer to his theory using this moniker.

3 However, readers familiar with Piaget's work will find resonances in his theorisation of assimilation and accommodation in Vygotsky's work.

provides the basis for developing a theory of instruction that can be used to understand pedagogy in context.

First generation Activity Theory: from Vygotsky to Leontiev

Central to Vygotsky's thesis is the notion that the individual's interaction with objects in the world is mediated by cultural artefacts: signs, symbols and practical tools. Artefacts carry with them a history of use and are themselves altered, shaped and transformed when used in activities (Saljo, 1999). Vygotsky's developmental theory can be graphically represented in Figure 1 below.

Figure 1: First generation Activity Theory

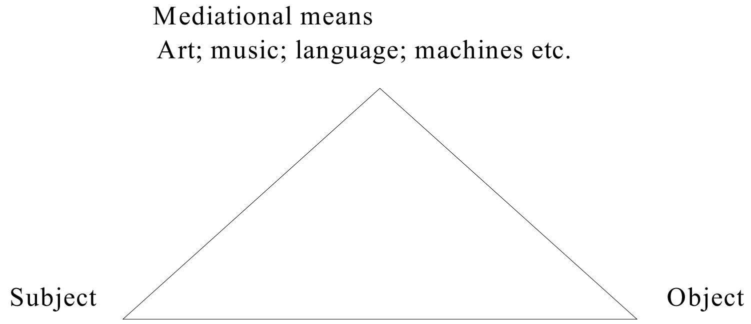
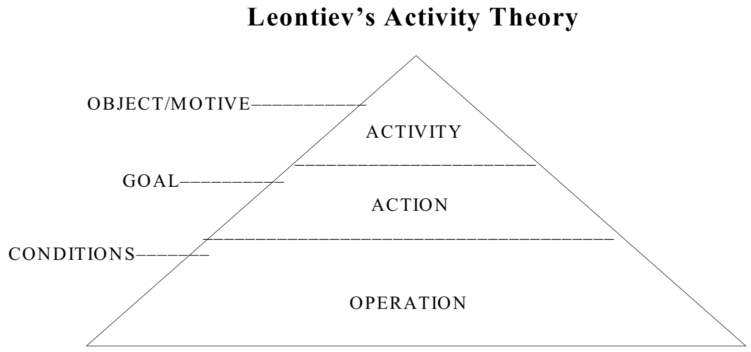


Figure 1 graphically represents how a human interacts with the world by means of cultural artefacts. The world is never approached directly in the course of the development of higher cognitive functions but is always mediated (Bateson, 1972; Wertsch, 1991). That is, the natural relationships represented at the base of the triangle become subsumed by cultural relationships represented at the apex of the triangle. The subject, an individual or group, uses *mediational* means in order to act on the object of the activity. A central premise of mediation is that a child can accomplish more with assistance than he/she can on his/her own. This notion of guided assistance is articulated in Vygotsky's work as mediation within the Zone of Proximal Development (ZPD) (Hedegaard, 1998; Daniels, 2001; Gallimore and Tharp, 1993; Moll and Greenberg, 1990; Cole, 1985). For Vygotsky (1978) the ZPD represents the gap between what a student can accomplish with assistance and what that student can accomplish on his/her own. This is a theoretical breakthrough with implications for pedagogy in that it implies that a teacher, or at the very least a culturally more advanced peer, is developmentally necessary, signposting the dialogical nature of learning (Diaz, Neal and Amaya-Williams, 1993; Gallimore and Tharp, 1993; Tudge, 1993; Cole, 1985; Moll and Greenberg, 1993). The ZPD represents a truly social concept; a move in Vygotskian theory from focusing on sign-mediated actions to socially mediated actions (Moll & Greenberg, 1990). This 'move' into socially mediated activity should be viewed in conjunction with the significance of tool and sign mediation, adding a broader social dimension to Vygotsky's (1978) developing theoretical system, providing an essential 'space' for educational intervention (Hedegaard, 1998). The central concepts of mediation within the ZPD provide a theoretical foundation for understanding how tool use can impact on practice. The notion of learning as mediated by a culturally more competent Other implies a pedagogy that aims to overtly structure and assist students. Unfortunately, Vygotsky's untimely death militated against him developing this aspect of his work.

Second generation AT: Leontiev to Engeström

In Vygotsky's (1978) notion of mediation within the ZPD we find a conceptual basis for theorising educational interaction in a classroom within an AT framework. While Vygotsky's learning theory points the way towards an understanding of learning as distributed, it does not develop an analytical framework capable of situating learning within a wider context, accounting for the collective and dynamic nature of activities (Engeström, 1987; Wells, 1999). Although the first generation of Activity Theory centres on Vygotsky's notion of mediation, this notion is still located at the level of the individual's actions and does not go far enough to illustrate how cognitive change happens within a collective context. The distinction between individual action and collective activity implied, but not articulated in Vygotsky's theory, was elaborated by one of his colleagues, Alexei Leontiev whose famous example of the "primeval collective hunt" clarified the distinction between individual action and collective activity (1981, pp.210–213) and placed division of labour firmly within his definition of activity. Leontiev's hierarchical model of functioning conceives of activity as driven by the object, while individual actions are directed at goals, see Figure 2 (Engeström, 1987; Leontiev, 1981).

Figure 2: Second generation Activity Theory

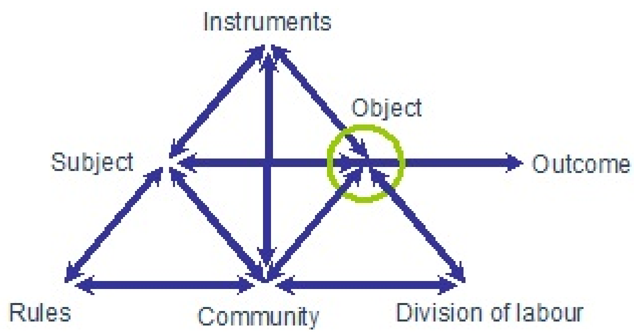


In this formulation, Leontiev is able to illustrate how motives, emotions and creativity are social endeavours, something that is quite difficult to do with Vygotsky's triadic model. This is achieved because this model of activity situates individual, goal directed actions in the social context of an activity. Leontiev's (1981) focus on division of labour as a central historical process in the development of higher cognitive functions and the hierarchical structure of activity that it implies, adds to Vygotsky's initial model of human action by illustrating how individual actions are goal oriented while collective activity is object oriented. Leontiev's three level model of activity represented in Figure 2 distinguishes between individual goal directed actions and operations and collective object oriented activity. Activity is driven by an object oriented motive, which is social; actions are conscious and are directed at goals and at the final, lowest level of the model, automatic operations are called into play by the tools and conditions of the action being carried out. In Leontiev's work we have a sense of how individual actions play out against the meaningful background of a social activity. This is something that is certainly hinted at in Vygotsky's work but it is ultimately not theorised. Leontiev enables us to see activity as a social endeavour, whereas Vygotsky's work is still located at the level of the individual acting with mediational means. Further, by indicating how division of labour is historically implicated in the development of higher cognitive functions, Leontiev points to the hierarchical structure of activity implied by division of labour. While accounting for hierarchical levels of human functioning, Leontiev's theory does not go far enough to situate human functioning in context, illustrating how individual actions are transformed into shared, *collective* objects through interactions with community members or indeed *how* division of labour impacts on individual actions in a collective activity. This is where Engeström's (1987) conceptualisation of an activity system (see Figure 3) as the basic unit of analysis serves as a useful tool for situating pedagogy in context.

Third generation AT: towards a theory of pedagogy as an *activity system:* Engeström

Figure 3 illustrates the basic unit of analysis (an activity system) proposed by Engeström's third generation Activity Theory model, which expands on Vygotsky's model (1987, p.78).

Figure 3: Activity System



What we can see from Figure 3 is that the *subject(s)* acts on the *object* in order to transform it using *mediating artefacts* in order to arrive at specific *outcomes*. In turn, the subject's position is influenced by the rules of the system, his/her community and division of labour (how the context is organised: this refers also to vertical and horizontal division of labour) (Daniels, 2001; Engeström, 1991; 1987). In this expanded version of Leontiev's work, the individual action represented at the pinnacle of the triangle is situated within a context in which power relations and rules impact on the subject's actions (Wells, 1999).

The notion of an activity system, then, illustrates how one might understand Leontiev's suggestion that actions can only be understood against the background of an activity; here we have a theoretical idea of what that 'activity' incorporates. Arising from Engeström's doctoral work (1987) this contemporary and popular version of AT is premised on the notion of learning as 'expansive'. The two way arrows indicate the dynamic nature of the nodes of the triangle. In this expanded version of Vygotsky's triadic formulation of mediated action, the individual action represented at the pinnacle of the triangle is situated within a context in which power relations and rules impact on the subject's actions (Wells, 1999). Engeström (1987; 2005) uses this notion of an activity system as the basic unit of analysis for developing his expansive learning theory, which incorporates a methodology for studying novel learning in a work place setting. This methodological aspect of Engeström's work does not inform this paper. Rather, this paper seeks to elaborate Engeström's systems thinking in relation to pedagogy. It must be noted, therefore, that the development of his work in this paper is the author's own and cannot be identified with his current project. Readers interested in Engeström's (2005) current project are referred to The Centre for Activity Theory at the University of Helsinki and to Daniels' (2001) and Daniels' and Leadbetter's (2005) development work research. For this paper, Engeström's systemic model enables one to view pedagogy along the following dimensions:

1. *Subject*: The subject of the pedagogical activity system is the teacher. The epistemic assumptions the teacher holds regarding learning will impact on how he/she uses the computer as a tool. Where a teacher believes that children learn through active engagement with the problem under discussion, s/he will use tools in different ways to a teacher who believes that knowledge is innate and that children learn in a passive manner.

2. *Mediating artefact*: In a crude formulation, one might view tools as resources mobilised by the teacher. Significantly, these tools mediate thought during the interaction between the subject and the context within an activity. These tools are both material (for example, the chalkboard) and psychological (for example language or symbolic systems such as algorithms). In this paper a distinction is drawn between non-linguistic and linguistic tools. So for example, while the chalkboard is a non-linguistic tool, the teacher's use of questions to open interaction is a linguistic tool.

3. *Object*: The object of an activity system represents that problem space that the teacher and students are working on. This concept is hotly debated in AT due in part to the fact that it is used differently by Leontiev and Engeström. Space constraints militate against an in depth discussion about the conceptual confusion surrounding this concept and interested readers are referred to Kaptelinin's (2005) discussion of this issue. For conceptual clarity, this paper draws on Engeström's understanding of the object as "the 'raw material' or 'problem' space' at which the activity is directed and which is moulded and transformed into

outcomes with the help of physical and symbolic, external and internal mediating instruments, including both tools and signs" (Engeström, 1987, p.79).

4. *Rules*: The norms, conventions and social interactions of the classroom, which drive the subject's actions are referred to as rules in AT. Rules in the classroom can, for example, be directives around appropriate behaviour (such as putting up one's hand when answering a question, rather than shouting out) or could relate to how the teacher treats the children and expects them to treat each other. The notion of rules in AT is somewhat general. 'Norms' for example could encompass a number of beliefs, or strategies such as the use of praise as a normative strategy. For this study rules can be defined broadly as of two kinds: rules related to the social order and rules related to the instructional context. This understanding draws on Daniels' (2001) and Bernstein's (1996) work. Instructional rules can be separated into evaluative rules that communicate the criteria for the production of a legitimate text and rules of pacing. Rules of the social order refer to behavioural rules and rules governing communicative interaction between teachers and taught.

5. *Community*: The teacher is a member of a community who participate in acting on the shared object. There is division of labour within the community, with responsibilities, tasks and power continuously being negotiated (Cole and Engeström, 1993). In the case study reported here the community comprises the teacher and the students who work together on a shared problem in the mathematics classroom. In a wider sense, the teacher and students are members of the community of the school; teachers are members of teacher unions or members of a community of mathematics teachers.

6. *Division of labour*: This is both vertical and horizontal and refers to the negotiation of responsibilities, tasks and power relations within a classroom as well as across the school. The focus in this paper is specifically on division of labour in the classroom, between teacher and students and students and students. This plays out in the roles that participants occupy in the lesson. In general, the teacher's role in the classroom is to teach and students' roles are to learn.

The study

This paper forms part of a larger study that investigated how teachers use computers to mediate mathematics and whether the introduction of this novel technology impacts on their pedagogical practices. This necessitated the development of a language of description capable of tracking pedagogy in face-to-face lessons, before embarking on a comparison of pedagogy across contexts. Through detailed analyses of teachers teaching, interviews with teachers and students, classroom observations and analysis of students' productions (such as workbooks or board work), the study set out to investigate pedagogical practices in four grade 6 classrooms. An exploratory multiple case study design was employed in order to best investigate how teachers teach. The sample comprised four previously disadvantaged primary schools in the Western Cape region of South Africa. Four grade 6 classes (153 children) and four grade six mathematics teachers participated in the study. This paper reports on one teacher's face-to-face practice. Mr Botha teaches at a school in a farming district about 120 kilometres outside of Cape Town. He has been teaching for 8 years. According to the principal of the farm school where he teaches, only one third of parents are able to pay the R30 (GBP 2.12) annual school fees. Data were collected in this particular school over the space of 16 months. Here an example of pedagogical practice in a face-to-face lesson serves to animate the analytical framework discussed below.

Analytical framework

Developing Engeström's systems thinking in relation to pedagogical practices in schools has necessitated the development of an analytical framework capable of analysing data gathered primarily from classroom observations. The chosen focus of the analysis described here is primarily on teacher and student talk as it encodes rules, tools, division of labour, object and the outcome of the activity. Although focusing the analysis primarily on talk, the use of material tools and the impact teaching and learning space has on division of labour is also investigated. Three analytical steps are involved in investigating observational data: first, a large body of data, representing 22 hours of classroom videos is transcribed and analysed for evaluative episodes, analytical spaces in the data that surface the object of the activity. These episodes represent disruptions in the pedagogical script where the teacher restates the evaluative criteria required to generate a legitimate text (Hardman, 2005a; Hardman, 2007). That is, the essence of this event is to be found in the evaluative criteria that it explicitly highlights. It is in the foregrounding of these rules that one is able to track the object of the episode. The restatement of the evaluative criteria in the episode provides us with a microcosm of the object of the lesson as a whole by highlighting what it is that the teacher and students are working on in the lesson. These episodes are then analysed using the AT categories. In first approaching the evaluative episodes, Table 1 serves as a starting point in order to develop a picture of what was happening in each episode.

Table 1: An AT checklist

AT concepts	Questions to ask when analysing evaluative episodes
Outcomes	What is produced in the episode?
Mediating artefacts	What tool(s) is/are used?
Object	What is the object/focus of this episode? What is the purpose of the activity for the subject? What is the teacher working on? Why is s/he working on it?
Division of labour	Who does what in this episode? Who determines what is meaningful?
Community	What community is involved in this episode? What group of people work together on the object?
Rules	What kinds of rules: instructional rules=evaluative rules and pacing rules? Social order rules=disciplinary rules and communicative interaction rules

The checklist elaborated in Table 1 informed the development of a more detailed coding schedule (Table 2) that was capable of comparing pedagogical practices across context. The checklist in Table 1 provides a broad picture of what is happening in the evaluative episode. However, it is not sufficiently refined to allow for comparisons across a large number of episodes. It does, however, provide the researcher with a base from which to develop a more detailed schedule that can be used to analyse a large corpus of data. The AT coding schedule developed from this initial checklist is used to carry out a comparative analysis between face to face pedagogy and computer based pedagogy along the various dimensions outlined in AT. Drawing on the AT concepts of tools, rules, division of labour, object, and outcomes (discussed above) 20 indicators were identified with which to analyse the evaluative episodes (Table 2).

Table 2: Analysing tools with the AT coding schedule

Level one				**Restricted**		**Elaborated**	
Tools	Linguistic tools		statements transmitting mathematical content	1	2	3	4
			questions transmitting mathematical content				
			statements transmitting task skills				
	Non-linguistic tools		chalkboard: generative use				
			chalkboard: representational use				
			computer: generative				
			computer representational use				
			other: generative use				
			other: representational use				
Rules	**Instructional**	Evaluative	evaluation of students' productions: explicit vs. implicit				
				Low teacher control		High teacher control	
		Pacing	Time on task				
	Social order	Order/ Discipline	Classroom management				
		Communication relations	Teacher-learner talk time				
			Teacher questioning				
			Questioning to promote interaction				
Object				Localised		Specialised	
			focus of episode				
Level two				**Symmetrical power**		**Asymmetrical power**	
Division of labour	Non-linguistic		Strength of boundaries between teaching and learning spaces				
	Linguistic		teacher student interaction: teacher roles				
			teacher student interaction: student roles				
Outcome				Localised		Specialised	
			type of object	1	2	3	4

Read from left to right, the table measures pedagogical practices across the AT dimensions across four scales. Tools and evaluative rules are analysed on a Likert scale from 1–4 in terms of whether they function to elaborate mathematical content [4] or not [1] and whether they accomplish this through representative or generative use. The terms representative and generative are drawn from Hokanson and Hooper's (2000) work where they draw a distinction between whether a tool (in their article a computer) serves to represent work that has been covered or whether it serves to generate novel thinking. Rules of pacing and the social order are investigated in terms of the degree of teacher control exercised. Where teachers exercise low degree of control over these rules this is captured as 1 or 2 on the scale; high degrees of control are captured as 3 or 4. The object of the episode is analysed in terms of whether it refers to the development of students' localised, situated knowledge [1] or specialist, abstract knowledge [4] as determined by the function of teachers' utterances. For example, in Table 3 below, one can see that where more than 50% of teachers' utterances function to explain mathematical content and the teacher uses probing questions to develop students' metacognitive skills, we would say that the object of the activity is very specialised [4].

Table 3: The object of the episodes

Indicator: Focus of episode			
1. Very low degree of specialisation	**2. Low degree of specialisation**	**3. High degree of specialisation**	**4. Very high degree of specialisation**
Most teacher utterances (over 50%) function to regulate students' actions in order to cover tasks	Most teacher utterances (over 50%) function to transmit technical skills	More than 50% of teacher utterances (statements and questions) function predominantly to develop and reinforce students' content knowledge	Over 50% of teacher utterances (statements and questions) function to explain mathematical content. More than 15% of teacher talk takes the form of probing questions to develop students' metacognitive skills.

The continuum referred to here is between knowledge with a very low degree of specialisation such as localised skills [1], which are related to the immediate context and are practical and concrete, and knowledge with a very high degree of specialisation [4], such as abstract decontextualised subject content knowledge (in this paper, mathematical knowledge). Using a computer mouse, for example, represents a localised skill whereas being taught how to add fractions, represents a high degree of specialisation. This distinction draws on Vygotsky's notion of everyday and scientific concepts, with everyday concepts referring to the development of empirical knowledge and scientific concepts serving as the basis for the development of theoretical knowledge (Karpov, 2003). Scientific concepts, or what Hedegaard (1998) has called 'schooled concepts', are mediated in a structured instructional setting where a more competent peer or teacher provides guided assistance to the less competent novice. While both [3] and [4] on the continuum refer to the development of students' specialist mathematics knowledge, the difference between [3] and [4] on the continuum relates to the development of students' reflective or metacognitive understanding of mathematics. Where the teacher explicitly requires students to give reasons for why they solve a problem in specific ways and encourages them to reflect on their problem-solving actions, the object [4] is a relatively higher-order object than [3].

A second level of analysis which draws on findings regarding tool use, rules and the nature of the object acted on, enables one to develop a picture of division of labour within an episode. Division of labour is measured on a scale in terms of whether power relations between teachers and taught are relatively symmetrical [1–2] or asymmetrical [3–4]. This is determined in terms of the roles that students and teachers enact in the activity. How teachers use tools, both material and linguistic, to act on certain objects in a context in which rules afford and constrain behaviour tells us something about the teacher's role in the classroom. Hence, this second layer of analysis focuses on how teachers use tools in a rule bound context to act on a particular object. This analysis provides the basis for identifying certain roles in the activity under investigation. These roles, then, are read off actual tool and rule use as they play out in the activity and are, therefore, determined through an analysis of an actual activity. In the case of this paper and the data that generated it, four teacher and student roles emerged from the analysis. These roles are elaborated in Tables 4 and 5 below.

Table 4: Synthesis of the analysis: division of labour enacted as roles

Power	Role	Tool use	Object	Rules
Symmetrical	1. Mediator	Over 10% of questions promote reflection. More than 25% of teacher's overall talk is teaching questions; More than 25% of teacher talk elaborates math concepts. 0% of teacher's talk is technical task skills Over 20% of overall discourse is students' engagement. Material tools serve predominantly generative function	Development of metacognitive skills	Elaborated evaluative rules; Low degree of teacher control over pacing and social order rules
	2. Instructor	0% of questions promote reflection. More than 25% of teacher's overall talk is teaching questions More than 25% of teacher talk elaborates math concepts 0% of teacher talk is technical task skills 10–20% of overall discourse is students' engagement Material tools serve primarily representative function	Development and reinforcement of students' understanding of mathematical content knowledge.	Elaborated evaluative rules; Low degree of teacher
Asymmetrical	3. Director	0% of questions promote reflection. 0–10% of teacher's overall talk is teaching questions 0–10% of teacher talk elaborates math concepts Over 25% of talk is technical task skills 0–10% of overall discourse is students' engagement Material tools serve primarily representative function	Development of students' technical task skills	Evaluative rules not elaborated; High degree of teacher control over pacing and social order rules
	4. Manager	0% of questions promote reflection. 0–10% of teacher's overall talk is teaching questions 0–10% of teacher talk elaborates math concepts 0% of talk is technical task skills 0–10% of overall discourse is students' engagement No use of material tools	Control of students' actions	Evaluative rules not elaborated; Very high degree of teacher control over pacing and social order rules

On a continuum from asymmetrical [4] to symmetrical [1] (moving vertically under the heading 'power') the instructor role, for example, is viewed as enacting relatively symmetrical power relations because the teacher asks questions that elicit student interaction and students are able to gain talk time. The difference between the instructor and mediator roles lies in the type of interaction between teacher and student facilitated by the use of verbal tools such as questions. In the mediator role the teacher uses probing questions and material tools in order to develop students' reflective capacity. While instruction is obviously a key feature of mediation, the differences mentioned here distinguish these roles in *this* study. The director role is characterised by the transmission of technical task skills. The teacher's role here is largely to direct students' access to new technology in an efficient manner. There is little student verbal engagement but a substantial amount of student kinaesthetic engagement with technical skills. Finally, the management role allows for almost no student engagement and sets up very clear asymmetrical power relations with the teacher in 'charge'. Roles are not static and the same teacher might inhabit different roles across episodes. Some episodes for example come fairly early in a lesson and might reflect the teacher's need to manage an unruly lesson, while episodes later in the lesson might focus more on teaching enabling the teacher to shift from a management to an instructor role. Associated with specific teacher roles, certain student roles emerged through the analysis of tool use, object and rules. Table 5 provides a summary of the types of student roles that emerged in the analysis. Each type of student role is associated with the teacher's role. So for example, the enquirer and respondent student roles are associated with the teacher's role of instructor. The enquirer role indicates a level of symmetry in the relations between teachers and taught because the student is able to gain talk time through questioning. The respondent role is associated with less symmetrical power relations between the teacher and the students as students engage in talk time only when called on to do so. The reflector role is associated with the teacher's role of mediator and indicates a symmetrical power relation between the teacher and the students as students are given space in which to reflect on their problem-solving actions. The performer role, where the student merely performs as instructed by the teacher, is associated with the teacher roles of director and manager. The performer role is indicative of the most asymmetrical power relations between the teacher and his/her students as students gain very little access to the pedagogical discourse in this role.

Table 5: Division of labour: student roles

Power	Role	Tool use	Object	Rules
Symmetrical	1. Enquirer	25–50% of student talk is answering questions Over 10% of student talk is mathematical questions 0% of talk is elaborating mathematical content. Students occupy over 10% of discourse	Mathematical understanding	Low/very low teacher control over pacing and social order rules
	2. Reflector	25–50% of student talk is answering questions 0% of student talk is mathematical questions Over 10% of student talk elaborates math content Students occupy over 10% of discourse	Metacognitive skills	Low/very low teacher control over pacing and social order rules
Asymmetrical	3. Respondent	25–50% of student talk is answering questions 0% of student talk is mathematical questions 0% of student talk elaborates math content Students occupy over 10% of discourse	Math understanding	Low teacher control over pacing and social order rules
	4. Performer	0–10% of student talk is answering questions 0% of student talk is mathematical questions 0% of student talk elaborates math content Students occupy 0–10% of discourse	Technical skills and conduct	High/very high teacher control over pacing and social order rules

Finally, as with the analysis of the object, the outcome of the activity is measured in terms of whether it is a localised, technical object or whether it is a more specialist, conceptual one. As there are several indicators for tools, rules and division of labour, an overall score of these indicators is obtained for each indicator by adding the scores and generating and average. This provides one with a single score for, say tool use, in an activity.

In a bid to reduce inference bias when using the schedule, a decision was taken to code utterances and count them, generating a frequency count for various types of utterances encoding various aspects of the AT dimensions discussed earlier in the paper. Hence, rather than using a traditional likert scale which refers to rather vague terms such as ‘a little’ or ‘most’, the schedule tries to mitigate inference effects by referring to actual percentages of utterance. So where 76% of a teacher's utterances elaborate mathematical content this would be captured as [4] in term of the descriptors illustrated in Table 6.

Table 6: Use of language to elaborate mathematics

TOOLS	**Linguistic tools**		
Indicator	**Mathematical content statements**		
1. Restricted Principles and procedures implicit	**2**	**3**	**4. Elaborated** Principles and procedures explicit
0–24%* of teachers' discourse explicates/elaborates mathematical content.	25–49% of teachers' discourse explicates/elaborates mathematical content.	50–75% of teachers' discourse explicates/elaborates mathematical content.	76–100% of teachers' discourse elaborates mathematical content.

* All language used in the episode is coded and frequency counts are generated. See the appended table for a definition of codes.

An empirical example: the AT coding schedule

The following extract is drawn from a lesson on the function of the denominator. It is quoted and analysed at some length in order to illustrate how one might use the coding schedule outlined in Table 2.

Evaluative episode in Merryvale[4] Primary School: the relationship between parts and a whole

Teacher and student talk	**Codes**	**Definition**
1. **Mr Botha:** question?	**QM2**	Teaching questions that open interaction
2. **Wayne:** explain the denominator again sir? *(puts up his hand)*	**QM2**	
3. **Mr Botha:** right, explain the denominator again.		
4. Come let's go further. (*Gets another apple)*		
5. Now, what is this? (*holds up an apple*)	**QM2**	
6. Students: whole (*choral response*)	**R**	Response
7. **Mr Botha:** whole.	**F2**	Elaborated feedback
8. And I cut him exactly, exactly, in how many parts?	**QM2**	
9. How many parts are there?		
10. **Students:** two	**R**	

4 All place and person names are pseudonyms.

11. **Mr Botha:** now, my denominator tells me how many parts I have divided my whole into (*holds up parts*)	**M2**	Elaboration of math.
12. In this case, it's two. (*holds up parts*)	**M2**	
13. So my denominator in this case will be?	**QM2**	
14. **Students:** two	**R**	
15. **Mr Botha:** two.	**F2**	
16. And now I'm going to cut him further (*puts apple back together and begins to cut it again*).		
17. Again, exactly, exactly. (*cutting apple)*		
18. Let's pretend it's exactly (*smiling*)	**M2**	
19. **Walter:** Into a quarter		
20. **Mr Botha:** (*nods*) must [cut] him exactly, exactly. *(cuts apple)*		
21. and I cut him up (*cuts apple)*	**QM2**	
22. in how many parts? (*cuts apple– holds up pieces*)		
23. **Students:** Four	**R**	
24. **Mr Botha:** And if you look carefully, how many pieces? (*holds up pieces)*	**QM2**	
25. **Students:** four	**R**	
26. **Mr Botha:** four pieces.	**F2**	
27. This piece, he is my (*holding up a piece)*	**QM2**	
28. **Students:** quarter,	**R**	
29. **Mr Botha:** quarter	**F2**	
30. you are clever		
31. You are clever! *(smiling)*		
32. But these four pieces show me, if I put them together, they are my whole. (*puts pieces together again)*	**M2**	
33. But I want to know, what is my denominator?	**QM2**	
34. and my denominator is going to tell me into how many		
35. **Students:** parts	**R**	
36. **Mr Botha:** parts I have cut him into	**F2**	
37. and it is	**QM2**	
38. **Students:** four	**R**	
39. **Mr Botha:** four.	**F2**	
40. and Bokaas told us very nicely that denominator stands	**M2**	
41. **Students:** under	**R**	
42. **Mr Botha:** under.	**F2**	
43. Denominator tells us how many parts we have. (*goes up to the boy – Wayne– who asked the question and shows him the 4 pieces of apple*)	**F2**	
44. Ok now Wayne? *(Wayne nods)*	**M2**	
45. I give Wayne (*gives him a quarter*)	**M2**	
46. **Students:** a one	**R**	
47. **Mr Botha:** one of what?	**QM2**	
48. **Students:** the whole.	**R**	
49. **Mr Botha:** I give him one of the four parts.	**M2**	
50. so he sits with one of the four pieces (*writes on the board a 4 and then 1 over it– ¼*)	**QM2**	
51. and I sit with? (*holds up his pieces*)	**R**	
52. **Students:** 3	**F2**	
53. **Mr Botha:** 3 of the pieces (*writes ¾ on the board*)	**QM2**	
54. and if I take my three and I put the other piece with it (*puts the pieces together)*		
55. then I have	**R**	

56. **Harvey:** your whole	F2	
57. **Mr Botha:** my whole. (*on board: ¼ ¾ =*)		
58. come let me put in a plus ¼ + ¾	M2	
59. then I have 4/4	M2	
60. and then my numerator and denominator are the	M2	
61. **Students:** the same.	R	
62. **Mr Botha:** good.	F1	Feedback not elaborated
63. Good.		
64. **Hendrik:** so we add the numerator Sir?	QM2	
65. **Mr Botha:** yes, good. (*episode ends and teacher goes on to discuss work covered in the previous lesson)*	F1	

In the above extract 48 utterances are coded:[5] 35 teacher utterances and 15 student utterances (50 utterances). That is, teachers talk occupies 70% of the discourse and student talk occupies 30% of the discourse. The teacher in the extract is defining what a denominator's 'job' is by using linguistic tools as well as material tools such as an apple and the chalkboard. Investigation of the teacher's use of language as a tool indicates that 11 of the 50 coded utterances (22%) are concerned with elaborating mathematical content knowledge. Focusing solely on teacher utterances, one sees that 11 of 35 coded teacher utterances (31%) take the form of statements that elaborate mathematical content. The picture of elaboration of mathematical content shifts when one considers that the teacher uses questions (n=14 utterances; 40%) as tools to elaborate mathematical content knowledge. Taken together, then, 71% of all teacher utterances in this episode functions to elaborate mathematical content knowledge. This would be coded on the AT schedule represented in Table 2 as [3] in terms of the following descriptor

> **[3] Elaborated:** 50–75% of teachers' discourse [statements and questions] explicates/elaborates mathematical content.

All of the questions asked (100%) are teaching questions that function to elaborate mathematical content knowledge. This is analysed on the AT schedule as:

> **[4] Elaborated:** 76–100% of questions teach: explicating the mathematical content. Questions used mainly to teach.

None of the teacher's utterances function to elaborate technical task skills and this is recorded on the AT schedule as:

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5 Not all talk is coded; only utterances capable of being coded using the linguistic coding schedule derived by the research are coded. This schedule is appended.

> **[1] Restricted:** 0–24% of teachers' talk directs students' task engagement skills. Students work on their own and don't need a lot of teacher input in regards to going about completing tasks.

Although relying most heavily on language as a tool, the teacher makes use of the chalkboard and an apple to visually represent knowledge he is verbally explaining. He moves from using the concrete object (the apple) to representing the parts of the whole on the black board (62, 66, 67 and 68). His primary material tools in this episode, then, are the apple (which he cuts using a knife) and the chalkboard (which he uses to represent the abstraction he has been discussing in concrete form). Both these tools are used to illustrate properties of fractions with the purpose of developing students' understanding of fractions. By manipulating these tools to uncover the properties of the denominator (literally, to illustrate the denominator's 'job', line 5) it is clear that the teacher is concerned here with developing students' understanding of fractions, specifically their understanding of what the denominator's function is. He always uses the chalkboard in the episode as a tool to visually represent verbally encoded knowledge. This is analysed on the schedule as:

> **[4] Material tool always used to elaborate mathematical knowledge:** Teacher always uses tools to represent verbally encoded knowledge

The teacher uses tools in a context in which rules of the social order and instructional rules constrain and afford behaviour. In this instance, the teacher 1) elaborates evaluative rules in lines 7, 15, 26, 29, 36, 39, 42, 43, 53, 57 and 2) does not elaborate evaluative criteria in line 62. The elaboration of evaluative criteria takes the form of asking leading questions to elicit students' interaction in solving the problem. The teacher elaborates why an answer is right by illustrating how one arrives at such an answer. He does this through cutting the apple and asking leading questions. The predominant use of evaluative feedback to elaborate evaluative criteria in this extract is analysed as:

> **[4] Elaborated:** Over 76–100% of teachers' *evaluation of students work explicates/elaborates* why an answer is right/wrong. The rules for what counts as a valid answer are explicit.

While evaluative rules are analysed in terms of the extent to which the teacher *elaborates* evaluative criteria pacing rules are evaluated in terms of the degree of teacher control over pacing. In this episode students, such as Wayne are able to disrupt pace and ask questions. None of the teacher's utterances are coded as pacing utterances and pacing is analysed in this extract in the following way:

> **[1] Low degree of teacher control over pacing:** 0–24% of Teacher talk *hurries* students up or to direct their task oriented actions in time (keep the lesson flowing and avoid disruptions to the pace of the lesson). Students can decide when to move onto the next exercise.

Social order rules are analysed in terms of levels of teacher control over 1) behaviour and 2) communication relations. There are no behavioural prescriptions in this episode and disciplinary norms appear to be controlled by the instructional context, most notably in this instance by the rigid Initiate Respond Evaluate (IRE) discourse structure, rather than overtly by the teacher (Wells, 1999). This would be analysed on the AT schedule as:

> **[1] Low teacher control over disciplinary norms:** 0–24% of teacher talk contains overt behavioural rules. Students may have internalised certain routines and disciplinary norms; they are able to control their own behaviour without the teacher having to tell them what to do. The instructional context demands certain ways of acting. Children are well behaved because they have internalised the 'normative' gaze.

The high incidence of mathematical talk in this episode indicates that the teacher is focused on developing students' understanding of mathematics; in this instance getting them to understand fractions. This is suggestive of a specialised object: the development and reinforcement of students' mathematical content knowledge.

Finally, the extract can be understood in terms of division of labour by asking who does what in the episode and investigating how space facilitates the enactment of certain roles. Division of labour is arrived at by analysing how teachers and students use tools and rules in the activity to enact certain roles. The teacher's role in this episode is analysed as 'instructor' according to the following descriptor:

> **[2] Instructor role: Tool use:** More than 30% of teacher's overall talk is 'teaching questions'; more than 40% of teacher talk elaborates math concepts. 10–19% of overall discourse is student engagement. Material tools are predominantly used as representational tools.
> **Object:** Development and reinforcement of students' understanding of mathematical content knowledge.
> **Rules:** Elaborated evaluative rules; low degree of teacher control over pacing and social order rules

On a continuum from asymmetrical [1] to symmetrical [4] the instructor role is viewed as enacting relatively symmetrical power relations because the teacher asks questions that elicit student interaction and students are able to gain talk time through asking and responding to questions. Although students' tend to speak only in response to the teacher, the students are able to pose questions as Wayne does in line 2 and Hendrik does in line 65. That is, of the 15 coded student utterances, 2 are questions (13%). The student role is an active role in this extract and is captured on the AT schedule as:

> **[1] Enquirer role: Symmetrical power relations** While still predominantly answering questions (25–50% of student talk) at least 10% of student talk is in the form of questions regarding subject content knowledge (i.e. not management questions).

Although power relations are relatively symmetrical in this episode, there is a firm boundary between teaching and learning spaces in this episode. There is a firm distinction between teaching and learning spaces with the teacher spending the entire episode at the chalkboard which represents the teaching space. This is captured on the schedule as:

> **[4] Asymmetrical: Firm spatial boundaries.** 0–24% of episode teacher spends away from the board/desk. Clear demarcation between teaching and learning space. Teacher and students remain in their own spaces– teacher at chalkboard and students in their desks.

Captured on the AT schedule elaborated earlier, this episode is represented in Table 7 below.

Table 7: Coding an evaluative episode

Level one					Restricted		Elaborated	
					1	2	3	4
Tools		Linguistic tools		statements transmitting mathematical content			■	
				questions transmitting mathematical content				■
				statements transmitting task skills	■			
		Non-linguistic tools		chalkboard: generative use	■			
				chalkboard: representational use				■
				computer: generative				
				computer: representational use				
				other: generative use			■	
				other: representational use		■		
Rules	**Instructional**	Linguistic	Evaluative	evaluation of students' productions: explicit vs. implicit				■
					Low teacher control		High teacher control	
			Pacing	time on task	■			
	Social order		Order/ Discipline	classroom management	■			
			Communication relations	teacher-learner talk time			■	
				teacher questioning			■	
				questioning to promote interaction	■			
Object					Localised		Specialised	
				focus of episode				
Level two					Symmetrical power		Asymmetrical power	
Division of labour		Non-linguistic		strength of boundaries between teaching and learning spaces				■
		Linguistic		teacher student interaction: teacher roles		■		
				teacher student interaction: student roles	■			
Outcome					1	2	3	4
				type of object			■	

The first AT category analysed in Table 4 is tool use. Here there is a distinction between linguistic and non-linguistic tools. The teacher uses statements [3] and questions [4] as tools to elaborate mathematical content knowledge, rather than to elaborate technical task skills [1]. Overall linguistic tool use is calculated by deriving an average of 3+4+1= 3. The chalkboard always serves as representational tools to elaborate mathematical content [4] but is never used as a generative tool [1]. Overall material tool use is calculated as: 1+4+3+2+4= 3. That is, material tools are used to elaborate mathematical content knowledge. The teacher also makes use of other tools (such as an apple and knife) to serve both representational [2] and generative functions [3]. None of the teacher's talk is used to elaborate task skills [1]. Evaluative rules are elaborated [4] in a context in which the teacher exercises low levels of control over social order [2] and pacing [1] rules. The object is the development of students' specialised understanding of mathematics [3]. Power relations are relatively symmetrical with the teacher occupying an instructor role [2] and students enacting an enquirer [1] role. An overall value of tool use, social order rules and division of labour is obtained by averaging the values for individual indicators. This teacher's pedagogical practice in this specific episode can be graphically represented as an activity system in Figure 4 below.

Figure 4: The activity system of an evaluative episode

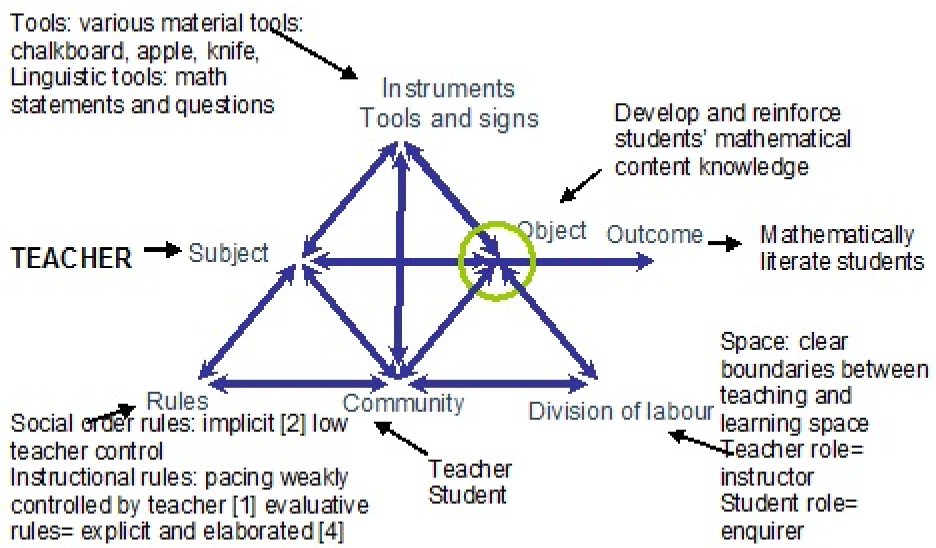

Figure 4 highlights how this teacher, acting in his role of instructor, uses statements, questions and various material tools to elaborate mathematical content knowledge in a context in which evaluative criteria are elaborated and the teacher exercises a low degree of control over rules of the social order and pacing. Tools are used to act on the object of developing and reinforcing students' understanding of mathematical content knowledge.

Conclusion

This paper presents a methodological discussion regarding how to use AT to study pedagogy in primary schools. The strength of AT as a heuristic device for understanding empirical data lies in its ability to account for human activity as a dynamic activity system. With its ability to describe practice in context, AT provides a potentially fecund methodological tool for analysing pedagogy as more than an investigation of student/teacher interaction. However, AT is not operationalised to study pedagogy and it is this methodological gap that the paper seeks to address by developing a language of description from AT with which to investigate classroom observations. The development of an AT coding schedule with which to analyse classroom observations provides a picture of pedagogy in context.

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Appendix 1: Categories for the Analysis of Discourse

The analysis is carried out at two levels. At the first level evaluative episodes are identified in the data. At the second level each utterance (defined as a unit of speech that is capable of being meaningfully understood on its own) is categorised according to the categories outlined below. Utterances were divided into two groups: questions and statements. Statements were categorised as those utterances that did not elicit a response.

Tool	Code	Definition
Mathematical content statement	M1: with no elaboration	Mathematical statements with no elaboration
	M2: with elaboration	Elaboration of how and why one solves maths problems using a variety of scaffolding techniques.
Math questions	QM1: testing questions	Used solely to assess knowledge base and not to open teaching interaction; closed in nature.
	QM2: teaching questions	Open interaction by scaffolding students' engagement with the content under investigation: leading children from known to novel knowledge in a structured and guided manner.
	QM3: probing questions	'Why' questions requiring reflective engagement.
Technical task skills	TM1: task skills	These are technical skills that the child learns in order to use novel technology successfully.
Rules	**Code**	**Description**
Instructional: Evaluative rules	F1: no elaboration	No explanation is given regarding why a student's response is right/wrong. This category only arises in response to students' productions.
	F2: with elaboration	The teacher tells students why their answers are incorrect and, therefore, gives them an indication of how one goes about producing a legitimate mathematical text.
Pacing	P1:pacing	Overt verbal control over pacing.
Social order	S1: behavioural prescriptions: disciplinary norms	Teacher tells children how to behave.
	S2: communication relations	Refers to who controls communication in the lesson indicating the extent to which students have access to the pedagogical discourse in the lesson.

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