Education as Change
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/redc20

Viewing teacher transformation through the lens of cultural-historical activity theory (CHAT)

Ian D. Beatty [a] & Allan Feldman [b]
[a] University of North Carolina at Greensboro
[b] College of Education, University of South Florida
Published online: 15 Nov 2012.

To cite this article: Ian D. Beatty & Allan Feldman (2012): Viewing teacher transformation through the lens of cultural-historical activity theory (CHAT), Education as Change, 16:2, 283-300

To link to this article: http://dx.doi.org/10.1080/16823206.2012.745756

Education As Change, Volume 16, No. 2, December 2012, pp. 283–300

Viewing teacher transformation through the lens of cultural-historical activity theory (CHAT)

Ian D. Beatty
University of North Carolina at Greensboro
Allan Feldman
College of Education, University of South Florida

Abstract
Technology-Enhanced Formative Assessment (TEFA) is an innovative pedagogy for science and mathematics instruction. The 'Teacher Learning of TEFA' research project studies teacher change as in-service secondary science and mathematics teachers learn TEFA in the context of a multi-year professional development programme. Applying cultural-historical activity theory (CHAT) to the linked activity systems of professional development and teachers' classroom practice leads to a model of teacher learning and pedagogical change in which TEFA is first introduced into classrooms as an object of activity, and then made useful as a tool for instruction, and then—in rare cases—incorporated into all elements of a deeply transformed practice. Different levels of contradiction within and between activity systems drive the transitions between stages. A CHAT analysis suggests that the primary contradiction within secondary education is a dual view of students as objects of instruction and of students as willful individuals; the difficulties arising from this can either inhibit or motivate TEFA adoption.

Keywords: pedagogy, teacher change, professional development, activity theory

Introduction

Designing and conducting effective professional development experiences for in-service secondary science teachers, especially ones that promote deep and lasting pedagogical change, is difficult. Although several 'best practices' for teacher professional development have been articulated (Loucks-Horsley 1996; Supovitz & Turner 2000), designing effective programmes remains more of an art than a science. We believe a major reason for this is that the dynamics of teacher learning and pedagogical change are poorly understood, and we see a need for a detailed model of how, in the context of a sustained professional development program, teachers learn a new pedagogical approach and change their perceptions and practice.

In pursuit of such a model, we and our colleagues have been conducting a multi-year research project titled Teacher Learning of Technology-Enhanced Formative Assessment (TLT). We have chosen to study teachers' learning of a specific pedagogical method, Technology-Enhanced Formative Assessment (TEFA; Beatty & Gerace 2009). TEFA is sufficiently well-defined to support a targeted professional development programme, sufficiently innovative and challenging to require deep teacher change in adopting it, sufficiently effective to produce motivating results for teachers that attempt it, and sufficiently multifaceted and flexible to yield research results that should generalize to teacher learning of other pedagogies.

We previously presented a preliminary model for teacher change and learning of TEFA (Beatty et al 2008), which we called 'a model for the co-evolution of teacher and pedagogy' or, more concisely, 'the co-evolution model' (Figure 1). It describes a teacher's learning process in terms of four general constructs:

ISSN: Print 1682-3206, Online 1947-9417

DOI: 10.1080/16823206.2012.745756

(1) the alignment or misalignment (tensions) between a teacher's skills, views, and context, and his or her conceptualization of the pedagogy and attempts to enact it;
(2) the conflicts, struggles, and rewards he or she experiences as a result of these alignments and misalignments;
(3) the changes to his or her conceptualization of the pedagogy and to his or her ways of attempting it that occur in response to these conflicts, struggles, and rewards; and
(4) the changes to his or her skills, perspectives, and general 'way of being a teacher' that also occur in response to the conflicts, struggles, and rewards.

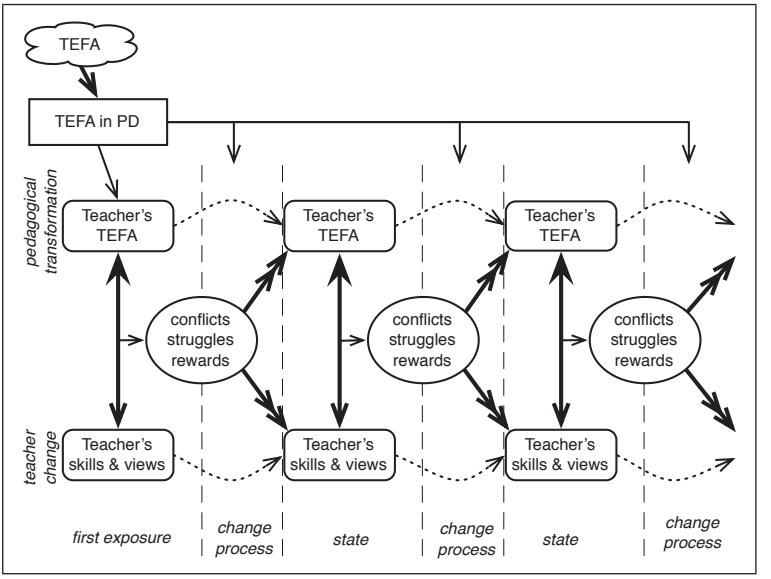

Figure 1: A model for the co-evolution of teacher and pedagogy (from Beatty et al., 2008).

The model represents the ongoing learning process of a teacher as an evolving dialectic between two primary narrative arcs. One, labelled 'teacher change', is the story of the teacher's growth as a practitioner, which encompasses acquisition of new skills, development of new perspectives, realization of new or newly emphasized values, and the like. The other, labelled 'pedagogical transformation', is the story of how the teacher perceives and interprets the pedagogy presented within professional development, and entails choosing which aspects to aspire to, consciously and unconsciously shaping it according to his or her perspectives and context, and evolving it over time. Within this model, tensions between the 'teacher's TEFA' and the teacher's identity and skills at any point in time are the primary driving force of change.

The model includes a third narrative: the sustained professional development experience that forms part of the teacher's context. This is another driving force for change, by challenging the teacher's personal understanding of and aspirations towards the pedagogy, suggesting alternative strategies for minimizing tensions, and supporting development of new skills and perspectives. (The diagram represents gradual change as well as discrete transitions.)

The co-evolution model has proven itself useful to TLT staff as a guide for professional development and research activity, largely by focusing our attention on two key aspects of the change process: the inevitability, and even desirability, of a teacher customising the pedagogy he or she has been presented

with; and the centrality of tensions and dissonances in driving change. However, the model fails to provide much help in identifying specific tensions that promote or inhibit change. It has two inherent weaknesses: It does not address the precise aspects of 'the teacher' and 'the practice of TEFA' that are relevant, and it does not adequately represent the greater context of interlocking agents and forces that both promote and constrain the process of change.

The first weakness can be addressed by connecting the narrative lines of 'teacher change' and 'pedagogical transformation' in the model to the literature on various ways of understanding how teachers change (Feldman 2002). Forging such connections is not the purpose of this paper, and will not be pursued here. Instead, we address the second weakness by connecting the co-evolution model to cultural-historical activity theory (CHAT), a framework or theoretical lens with a history of fruitful application to various education contexts (e.g. Henning 2008; Whitelaw, De Beer & Henning 2008). The remainder of this paper is a theoretical exploration of how CHAT can help us understand teacher change and pedagogical transformation within the context of sustained professional development.

Background: Cultural-Historical Activity Theory (CHAT)

In this section, we very briefly summarize the elements of CHAT that we will draw upon later in the paper. To do so, we rely on Yrjö Engeström's (2001) formulation of 'third-generation activity theory' and his analysis of the history of first- and second-generation activity theory.

First-generation activity theory originated in the work of Lev Vygotsky (Vygotsky 1978), who hypothesized that artifacts mediate all human action. These artifacts can be tools, such as hammers, ovens, or computers; cultural artifacts, including language; and theoretical artifacts, such as mathematics or feminist theory. Mediation occurs between the subject and the object of action, where the subject is typically an individual human being.

First-generation activity theory has been used to understand individual behaviour by examining the ways in which a person's actions performed on objects are culturally mediated. The unit of analysis is the individual, which limits researchers' ability to model collective activity and social influences upon a person. Alexei Leont'ev (1981) addressed this limitation by developing second-generation activity theory, in which the actions of an individual are seen as embedded within an activity system including the subject (individual), the object of action, and a community engaged in collective activity. Leont'ev asserts that many human actions make sense only when seen in the context of collective activity, wherein different people take on different roles according to a division of labor mediated by rules.

Engeström presented these elements and their interconnections visually in his now-famous 'triangle diagram' (Figure 2). The subject of the activity system is the person or sub-group whose actions we seek to understand: the point of view for our analysis. The object of the activity system motivates the actions of the subject, and can be thought of as 'the 'raw material' or 'problem space' at which the activity is directed (CATDWR 2003:par. 4). The subject uses tools, which can be physical, cognitive, or symbolic, to direct actions towards the object and to produce outcomes. The community consists of the participants engaged in collective activity with the subject, along with other individuals or groups with a stake in the object of activity. The object defines the community and distinguishes it from other communities (Engeström 2001; Murphy & Rodriguez-Manzanares 2008). Division of labour refers 'to both the horizontal division of tasks between members of the community and to the vertical division of power and status' (CATDWR 2003:par. 4). Rules both implicit and explicit, including regulations, norms, conventions, and other beliefs, shape the behavior of the community members.

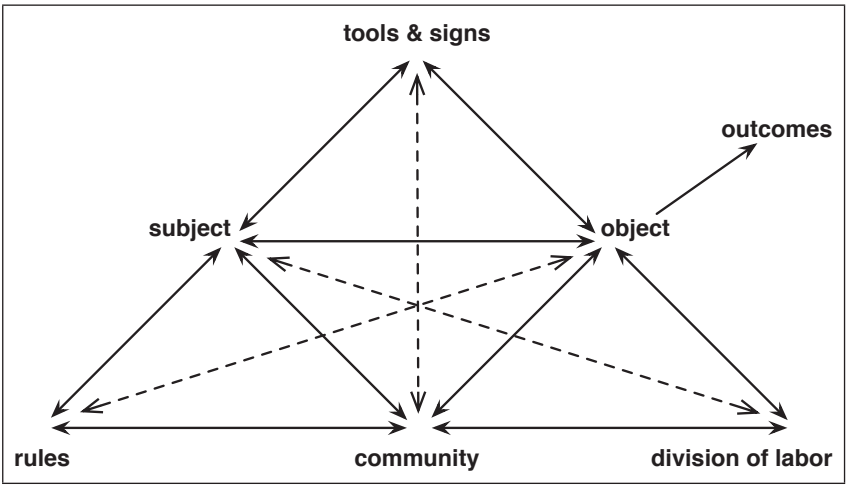

Figure 2: The cultural-historical activity theory (CHAT) 'activity system triangle' (after CATDWR, 2003).

Critics of second-generation activity theory, including Engeström (2001) and Wertsch (1991), point out its inability 'to understand dialogue, multiple perspectives, and networkings of individual activity systems' (Engeström 2001:135). This led to the development of third-generation activity theory, called cultural-historical activity theory (CHAT). Engeström (2001) summarizes CHAT with five principles:

> ***The first principle*** is that a collective, artifact-mediated and object-oriented activity system … is taken as the prime unit of analysis. Goal-directed individual and group actions … are … understandable only when interpreted against the background of entire activity systems ….
>
> ***The second principle*** is the multi-voicedness of activity systems. An activity system is always a community of multiple points of view, traditions and interests ….
>
> ***The third principle*** is historicity. Activity systems take shape and get transformed over lengthy periods of time. Their problems and potentials can only be understood against their own history….
>
> ***The fourth principle*** is the central role of contradictions as sources of change and development. Contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems …. Such contradictions generate disturbances and conflicts, but also innovative attempts to change the activity…
>
> ***The fifth principle*** proclaims the possibility of expansive transformations in activity systems. Activity systems move through relatively long cycles of qualitative transformations. As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from its established norms …. An expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity (136–137).

Contradictions within and between activity systems, the primary drivers of change and especially of 'expansive transformations', can be divided into four categories (Engeström 1987:82): a primary contradiction found within each constituent element of the system, secondary contradictions between elements of one activity system, tertiary contradictions between the object or motive of an activity system and the object or motive of a 'culturally more advanced' form of the activity, and quaternary contradictions between the activity system and other activity systems to which it is linked.

Empirical Context: Teachers' difficulties with TEFA

The context for our theoretical exploration is an analysis of the difficulties teachers encounter and the changes they undergo while learning to practice TEFA while supported and challenged by professional development. Although a detailed exposition of TEFA and the TLT project are beyond the scope of this paper, some knowledge of these is indispensable for understanding what follows. In this section, we briefly summarize TEFA, the TLT project, and the major difficulties teachers encountered in their learning of TEFA.

TEFA and TLT

Technology-enhanced formative assessment (TEFA) is an innovative pedagogical approach grounded on four principles: question-driven instruction, dialogical discourse, formative assessment, and meta-level communication. Each of these, independently, is of well-established value to science instruction (Beatty & Gerace 2009). TEFA integrates them into a powerful, coherent, self-reinforcing, tractable whole by structuring class time around an iterative 'question cycle' that consists of posing a question to the class; allowing students a few minutes to ponder alone or in small groups; collecting students' answers; presenting a summary of students' answers and their relative popularities; eliciting students' justifications for their choices; moderating a whole-class discussion around the relevant ideas; and providing appropriate wrap-up or closure. This cycle is facilitated by a classroom response system (CRS, a.k.a. 'clicker' system; Dufresne, Gerace, Leonard, Mestre & Wenk 1996; Fies & Marshall 2006).

'Teacher Learning of TEFA' (TLT) is a research project studying teacher learning and pedagogical change in the context of TEFA-focused professional development for in-service, secondary-level science and mathematics teachers. Initiated in 2005 and ending in 2012, it employed a longitudinal, staggered site, delayed intervention design, with 43 participating teachers from four sites. At each site, data collection spanned one baseline semester and two to three years of professional development. Project staff collected data on the participants' backgrounds, outlooks, experiences, and classroom practice of TEFA through multiple instruments and methods. Analysis was conducted via a mixed-methods approach, more qualitative than quantitative, leading to case study profiles (Yin 2003) and cross-case analysis.

The project staff developed a TEFA professional development program that incorporated known best practices from the in-service teacher professional development literature as well as prior research results on teachers' learning of TEFA (Feldman & Capobianco 2008). The program was intensive and sustained, beginning with a four-day summer workshop, continuing with a year of weekly and then bi-weekly after-school group meetings, and sustained by one or two additional years of monthly collaborative action research meetings (Feldman 1996). Staff modelled the TEFA pedagogy while teaching about it, and conducted the programme in accord with the four principles of TEFA.

Teachers' Difficulties Adopting TEFA

Analysis of TLT project data leaves little doubt as to the dominant difficulties teachers wrestled with when learning and attempting TEFA. We summarize them in approximately decreasing order of prevalence among participants.

Insufficient prep time

By far the most common and sustained difficulty TLT participants reported was finding time to create good questions to anchor the TEFA question cycle. The complaint of 'not enough time,' however, is not

fundamental: we can unpack it to reveal a conjunction of at least three underlying factors. The first factor is that the TEFA 'toolkit' presented to teachers in professional development included only a few formative assessment questions scattered across subjects and topics, intended as examples. Teachers needed to create their own questions. The second factor was that teachers, at least initially, had insufficient skill at question design to be efficient and reliably successful. The third factor was that most secondary school teachers are allotted very limited prep time during their working hours, and must do significant grading, lesson planning, laboratory equipment setup and maintenance, and other preparatory and administrative work in their personal time. 'Not enough time' can also be an excuse used to whitewash or soften some other barrier that the participant is unwilling to share with project staff. It can, for example, mean 'I'm not impressed enough by TEFA to prioritize it above the things that I currently spend my time on.'

Disappointing student participation

Another common difficulty identified by TLT participants was coaxing satisfactory student participation in the whole-class discussion portions of the TEFA question cycle. The number of students participating, the extent of student utterances, and the depth of thought articulated were all points of concern.

Insufficient class time

A difficulty that presented less of an immediate barrier, but posed a more serious long-term threat to adoption, was a perceived conflict between the time TEFA requires in class and the broad swaths of mandated curriculum that many teachers felt pressured to cover due to state frameworks and standardized exams. This difficulty is an incarnation of the classic 'depth vs. breadth' conundrum, not unique to TEFA.

The difficulty may also be illusory or avoidable. Some participants reported that TEFA 'felt' inefficient to them, and yet they actually covered their usual syllabus in less time than they had prior to adopting TEFA.

Technical difficulties

For almost all project participants, learning to operate the classroom response system technology and working around bugs and problems was a major obstacle and distraction for the first month or two of the project, largely due to idiosyncratic, school-wide problems with the technology at each site. Thereafter, a few participants wrestled with new or recurrent problems, but most resolved their difficulties and reached a comfortable level of skill. Inadequate school technical support remained a problem at all project sites, especially when hardware or software upgrades introduced new problems.

Student behaviour problems

Another difficulty that project participants contended with was controlling undesirable student behaviour during TEFA activity. To many teachers, practicing TEFA in the highly student-centered manner modeled in the professional development program felt like a dangerous relaxation of control, inviting misbehaviour of many kinds including inattention, disrespectful comments, side conversations, excessive fiddling with the CRS clickers, physically damaging the clickers, and making a silly game of CRS responses.

Clash with teaching style

All teachers have a personal 'style' of teaching, which we loosely define to include beliefs and preferences, orientations towards or against certain kinds of practices, areas of comfort and discomfort, and habits. TEFA may be more or less aligned with any individual's style. A point of stylistic conflict reported by some teachers was discomfort with the whole-class discussion phase of the question cycle. Another involved the degree and nature of pre-class preparation required by TEFA: some teachers found question preparation to clash with their spontaneous, ad-libbing style of instruction, whereas others disliked the surprises that TEFA interaction can produce.

Incompatibility with subject or curriculum

Some teachers reported difficulty fitting the TEFA approach into specific subjects or harmonizing it with specific curricula. One teacher at site B used the *Layered Curriculum* approach, which is based on highly asynchronous student seat-work and does not lend itself to the whole-class mode of instruction advanced by TEFA. Other teachers avoided using TEFA within laboratory-heavy units and courses, sometimes because of difficulty figuring out how to fit it in, sometimes out of a simple fear of having CRS student units in close proximity to liquids or other potentially damaging items. Sometimes, 'incompatibility with this course' simply meant that the teacher felt so much content-coverage pressure that difficulty 3 above, 'insufficient class time,' seemed prohibitive.

Variability among teachers

Interestingly, none of these difficulties was common to all participants. Some rarely found time to create TEFA questions, while others invented them easily. Some had difficulty eliciting participation from students, while others had difficulty getting students to stop discussing and move on to new topics. Some had no tolerance for the 'misbehavior' of inter-student side conversations, while others interpreted it as productive on-task peer interaction.

Theory: Applying CHAT to TLT and TEFA

As 'an accommodating framework … rather than a neat set of propositions' (Roth & Lee 2007:191), CHAT can be applied to secondary science and mathematics education, the TLT project, and teachers' learning of the TEFA pedagogy in many conceivable ways. We believe that no one application is 'right.' Rather, applications should be judged by their utility and self-consistency. In the following subsections, we first apply CHAT to the 'activity system' of TLT project professional development. We then apply it to the related activity system of an individual teacher's class. Building on these analyses, we suggest a model for a teacher's process of TEFA adoption and pedagogical change.

Co-evolution and CHAT for professional development

After an initial multi-day workshop, TLT professional development consisted of regular after-school meetings between facilitators and the participating teachers from one site (typically four to ten). The facilitators' aim throughout was to help participants understand TEFA, develop the skills to practice TEFA with success, adapt TEFA to their idiosyncratic situations and orientations, and solve problems that arose.

The professional development programme as an activity system

The first activity system we consider consists of the facilitators and participating teachers, engaged in the activity of 'TEFA professional development' with the goal of helping the teachers learn to use the pedagogy successfully in their classes. Within the CHAT 'activity triangle,' we identify the collection of facilitators and participating teachers as the community, and choose to focus on the viewpoint of an individual teacher as subject (Figure 3). The object of this system is that teacher's instructional practice, and the desired objective is successful implementation of TEFA to help students learn.

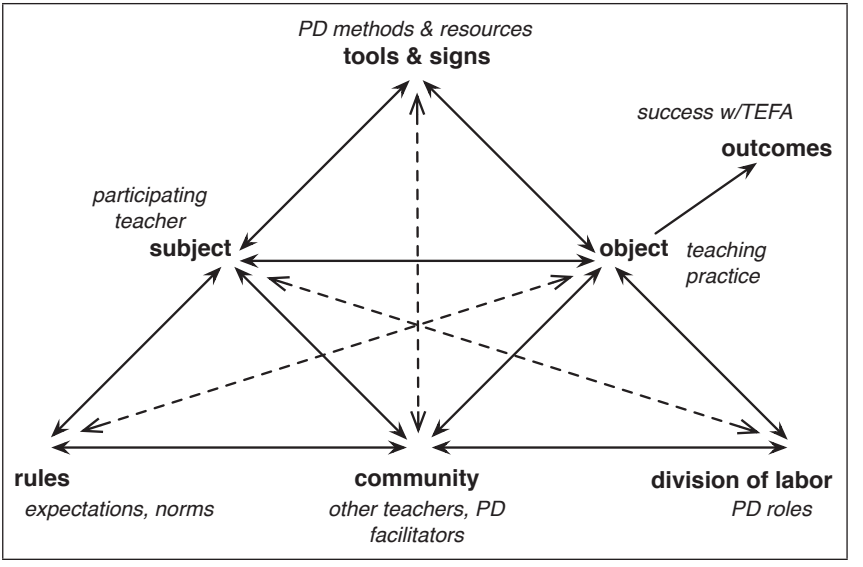

Figure 3: TLT project professional development as a CHAT activity system.

Within this system, the division of labour specifies the roles and responsibilities of the facilitators and teachers. These are complicated by the fact that facilitators were also part of a linked activity system of researchers conducting research with the teachers as subjects, giving them additional and possibly conflicting roles. The situation was further muddied by the fact that participants had the option of receiving graduate credit for the program, giving the facilitators yet additional roles that are typical of instructors, including 'setter of standards' and 'determiner of grades': roles that may not be entirely compatible with their facilitation and research roles. Facilitators attempted to minimize the impact of such conflicts by prioritizing facilitator responsibilities over others.

The rules element of the system was a source of tension, as many teachers felt that they were 'supposed' or 'obligated' to use TEFA with a greater frequency or in a different manner than they would choose purely for their own instructional reasons. Facilitators tried to balance reassuring participants that their instructional judgment was paramount with encouraging them to push beyond their comfort zone, and as a result may have sent mixed messages about the rules. Also at issue were emergent rules (unspoken agreements) about what professional development 'assignments' participants would or would not complete. Finally, the tools of the system include the many different professional development tactics and resources employed to help teachers reflect upon their practice and improve their skills.

The Co-Evolution Model and CHAT

The CHAT activity system just described connects with and complements the co-evolution model summarized earlier. The subject element of the system, the teacher, obviously corresponds to the 'teacher' box of the co-evolution model. The object element, the teacher's practice, corresponds to the 'teacher's TEFA' box. The influence of professional development on the teacher and his or her practice, which is left fairly vague in the co-evolution model, is expressed in CHAT as the influence of the community on the teacher, structured by the division of labor, mediated by rules, and expressed in part by the provision of tools.

While CHAT provides more structure to understand how professional development influenced teachers, the co-evolution model makes explicit two propositions only implicit in CHAT: the subject and object are in constant and interlinked evolution, and tensions between elements of the system drive this change. The co-evolution model adds a temporal dimension to the CHAT activity system.

We can also view the co-evolution model as a way of understanding the process of expansive learning discussed by Engeström (2001). Within the TLT project, teachers were not merely learning a set of pre-defined skills or acquiring 'stable knowledge'. They were also exploring and pushing back the horizon of the space of pedagogical possibilities open to them, participating in an ongoing re-conceptualization of what TEFA-based teaching could look like. We conjecture that a dialectical interaction of multiple narratives, analogous to the co-evolution model's 'teacher change' and 'pedagogical transformation' arcs, may be essential to any process of expansive learning.

CHAT for classroom instruction

The activity system just described is rather pointless in isolation. It only has value, and can only be properly understood, in the context of each participating teacher's classroom instruction. Thus, we turn the lens of CHAT to the activity system consisting of a secondary school teacher and his or her students, engaged in the activity of 'teaching a subject'.

The Classroom as an Activity System

Again, we begin by mapping the CHAT activity triangle to our system. Still adopting the teacher's perspective, we identify the teacher as subject (Figure 4). The object of the teaching/learning activity is the set of students. More precisely, it is the students' content knowledge that is the 'raw material' (CATDWR 2003:par. 4) for producing the desired outcomes of subject comprehension and readiness for standardized tests and subsequent schooling. The community includes other members of the school, such as support staff, counselors, administrators with disciplinary roles, and student teachers. The students should arguably be included in the community as well, giving them an ambiguous status: an ambiguity we examine below.

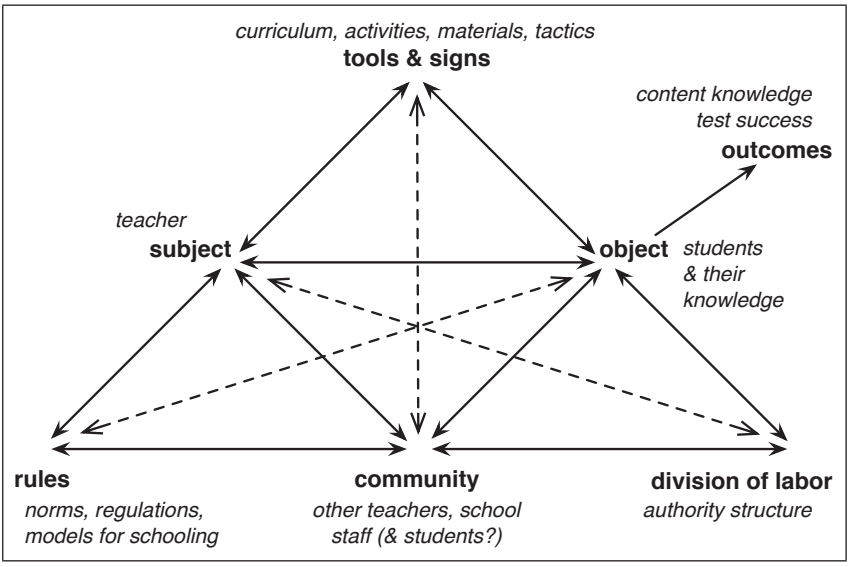

Figure 4: A TLT project participant's classroom instruction as a CHAT activity system.

The distribution of labour in the classroom specifies the power structure, including the teacher's authority to designate learning goals for students, select and design learning activities, establish performance criteria and measures, and dictate behaviour standards. Rules explicit and implicit (and varying among teachers and classes) specify norms and expectations for behavior. In particular, these include the teacher's and students' deep-seated, often unconscious models of what school teaching and learning 'should look like,' as well as implicitly negotiated (and often tested) thresholds of acceptability for borderline behaviours.

The activity system's tools include a wide array of teaching/learning resources, ranging from concrete items like whiteboards, computers, and textbooks to abstract patterns of action such as activity types, teacher questioning strategies, and recourses for disciplinary action. Most experienced teachers seem strongly attached to their toolkit: It forms a set of survival strategies and resources painstakingly collected to cope with the trying environment of the classroom, and they are cautious about tinkering with it for fear of the possible consequences (Cuban 1993).

The primary contradiction

'The primary contradiction [of an activity system] can be found by focusing on any of the elements' of the activity system: a 'primary inner contradiction (double nature) within each constituent component of the central activity' (CATDWR 2003, paragraph 16 & Figure 6). We take this to mean that every activity system has a deep, fundamental dichotomy or dialogical tension manifest in every component of the system. (We are uncertain whether this suggests that every activity system has at least one or exactly one such primary contradiction.)

We contend that the primary contradiction within secondary education is obvious to anyone who has spent time in a classroom: the endless clash between the teacher's goal of teaching subject material and his or her need to almost continually manage student behaviour and keep students 'on task'. That is, the activity system's division of labour has assigned to the teacher two conflicting roles: teacher of subject

content, and maintainer of order. We label this contradiction within the system's subject (the teacher) as the 'instructor|warden' contradiction. The vertical bar between 'instructor' and 'warden' indicates a dialectical category constructed from two mutually exclusive, reciprocal terms and encompassing an inherent contradiction (Roth & Lee 2007). Proceeding with the metaphor, we label the corresponding manifestation within the system's object, the student, as 'trainee|inmate.' From this, we believe the fundamental cause of the contradiction becomes clear: The activity system treats students as the object of activity, as if they were 'raw material … at which activity is directed' (CATDWR 2003:paragraph 4), despite the unavoidable fact that they are willful individuals making a transition to adulthood. Students' dual status as both object and community member is at the root of the contradiction. The issue is one of sovereignty and whether students act or are acted upon.

This primary contradiction reverberates throughout our system (Figure 5). It manifests itself in the community and the school that encompasses it as an 'academy|prison' dual nature. We label the subject-to-object relation (termed production by activity theorists) as 'instructing|controlling'. The teacher's tools, which mediate the subject-object relationship, must consequently serve the dual purpose of 'informing|holding responsible'. We find it telling that the two general questions prospective TLT participants most often asked about TEFA were 'Will it help students learn the content better?' and 'Will it get the students to participate and behave?' Two of the seven teacher-reported difficulties listed in the previous section can be seen as straightforward manifestations of this primary contradiction: 'Disappointing student participation' and 'student behavior problems' both mean 'students are choosing to do what they want to do, rather than what I want them to'. We believe many of the other seven difficulties can be indirectly traced to the primary contradiction as well. One example is the enactment of structures such as content frameworks and standardized tests to control behavior (of teachers as well as students) by the linked activity systems of school districts and governments.

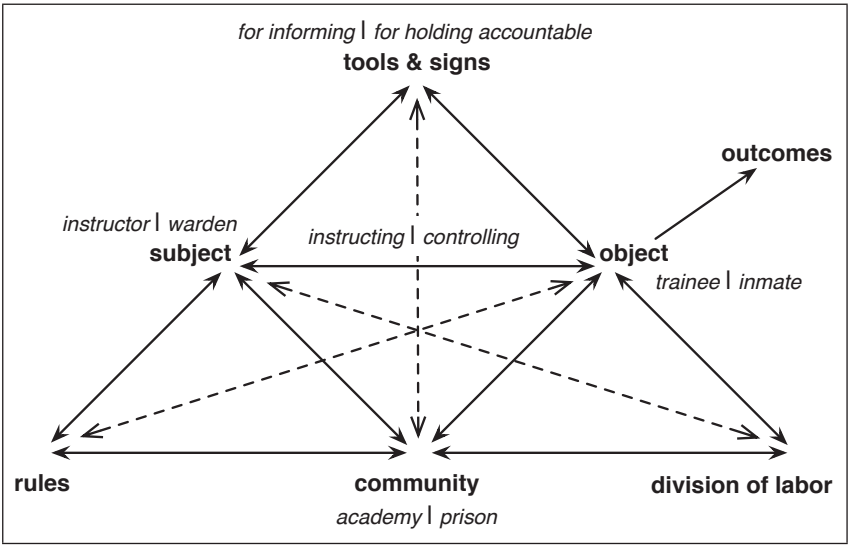

Figure 5: The 'primary contradiction' manifest within all elements of the activity system of classroom instruction.

Guided by CHAT, we suggest that the resolution to this primary contradiction is not to pull for one alternative or the other, but rather to transcend it through an 'expansive transformation,' escaping from the 'student as trainee | student as inmate' dichotomy to a system where the student might be described

as an 'explorer and seeker of knowledge'. This would require that the production dynamic of 'instructing | controlling' evolve into one of 'facilitating', the teacher evolve from 'instructor | warden' to 'guide and coach', the classroom and school evolve from 'academy | prison' to 'environment and resource', and the tools evolve from 'means of informing | means of holding accountable' to 'resources for engaging and exploring' (Figure 6). To put it another way, the escape from the dichotomy is to view learning as 'what students pursue' rather than 'what teachers cause.'

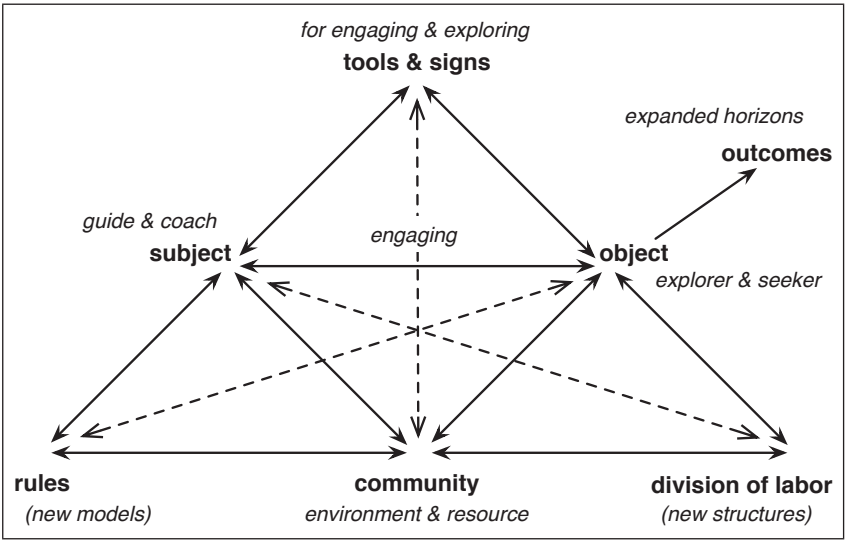

Figure 6: The activity system of classroom instruction, transformed to transcend the primary contradiction.

Such a transformation may seem utopian and unrealizable, requiring a drastic re-visioning and overhaul of the entire activity system and many coupled systems including teacher preparation programs, public education structures, and parental and societal perceptions. However, one of the participants in the TLT project demonstrated that a single teacher can, with a bit of support from professional development, achieve this transition in one classroom:

> I mean you come into my classroom; it looks chaotic from the onset. You don't see a teacher that is standing and all of the students sitting behind a desk and quietly, you know, staring at the teacher. You see some students at one whiteboard, students at a SmartBoard, students in little groups, you know, and all working on the same problem, and then all coming back together, and then students arguing. It seems kind of chaotic, but it's, it was so much learning happening that I think it was a risk worth taking …. I tried to get [the school administration] in there to see that, and see what a real learning classroom looks like. Because it was new for me, and it was exciting for me ….
>
> Sometimes as teachers we get in the way of our students' learning. Um, I think, that's why I think this back-of-the-classroom approach works ….
>
> I mean, the [CRS] clickers are just a tool we use to see where we're at at any given moment. Um, and for good or bad, I don't necessarily think 'Well, we're gonna include the [CRS].' There are times when I don't include the [CRS]; it's not a part of my plan. And the students say 'Let's poll this!' And they'll get up, they'll grab their clickers. I'll, you know, turn it up, and they turn and they all vote. And then they'll say 'Well, okay, um, most of us choose this, so we're gonna go with this'…. And then I look at it and we talk about it ….

I had one student that said to me 'I never liked math before, but this feels good.'

— participant b104, excerpts from pedagogical perspectives interview, year 1 (emphasis by speaker)

Aside from the teacher, the class in question – a heterogeneous 9th grade algebra class – was not particularly special in any way. This suggests that teachers have far more control over the dynamics of their classrooms than most believe. It also provides us with hope that our suggestion for transcending the 'informing | controlling' contradiction by escaping to a dynamic of 'engaging' is realistic and worth pursuing.

Illuminating TEFA Adoption with CHAT

We have just presented a CHAT-based description of the two linked activity systems central to a teacher's adoption of TEFA: the TLT project professional development and his or her classroom. Now, we build on these to suggest a model for how TEFA can be assimilated into a teacher's practice, with potentially transformative results.

Stage 1: TEFA as Another Object

At the outset, TEFA was not immediately useful for teachers' instructional goals. It was something new, unfamiliar, awkward, perhaps intimidating, and frequently troublesome: 'one more thing' to try to accomplish in class. The TLT participants made an effort to try it out in their classes because they hoped it would prove to be of value, and also because they felt obligated to by their participation in the project. We call this stage 'TEFA as object,' since their implementation of TEFA became an additional object for them to focus activity on.

[Day-to-day, the aspect of using TEFA I've been most focused on or concerned about is] trying to work with it and include it into my class as an important part.

— participant a105, monthly reflection survey for year 1 round 2

This created a new tension in the classroom activity system, as multiple objects (students and their knowledge, TEFA practice) and multiple outcomes (student learning, doing TEFA 'right') vied for scarce resources (class time, student attention span, teacher energy). To use the language of CHAT, we would say that the linked activity system of professional development injected an additional object and desired outcome into the classroom activity system, creating a quaternary contradiction between the two systems.

For some teachers, this uncomfortable state of affairs lasted for more than a year. For most, however, the tension stimulated change. Two forms of resolution occurred: abandoning TEFA, or finding a way to make TEFA aid rather than obstruct the teacher's primary instructional goals.

Stage 2: TEFA as Tool

The majority persevered, reaching a second stage that we call 'TEFA as tool'. This stage was characterized by a teacher's belief that TEFA use was productive for him or her in teaching students, and that the gains achieved were worth any additional effort required.

'I would.' 'Absolutely, I would.' 'Oh my God, yes.'

— responses from three participants to the focus group question 'If the project folded now and you got to keep your equipment, would you continue to use TEFA?' in site B year 1 professional development meeting 18.

In practice, the transition from stage 1 to stage 2 was rarely abrupt. Most participants found that TEFA became gradually more useful and less onerous: it now had utility for them, although whether it had enough utility to offset perceived drawbacks and displace other activities might not yet be obvious. Some teachers fluctuated, apparently backsliding on their degree of conviction. Some reported dramatic moments of epiphany, where a specific insight or occurrence altered their perception of TEFA's value.

> I think having one really amazing experience using TEFA — because I had a great question and it really worked — has restored my view that it's worth trying to find the time to design good questions and use TEFA.
>
> — participant a113, monthly reflection survey for year 1, round 4

As TEFA transitioned from object to tool in the classroom activity system, the quaternary contradiction identified above subsided. However, as mediator of the subject-object interaction, tools influence the activity of the system in fundamental ways. The incorporation of TEFA as a tool rather than object may have resolved the quaternary contradiction mentioned above, but it introduced secondary contradictions between TEFA and other elements of the system. We believe that many of the difficulties TLT teachers reported with TEFA can be understood as such secondary contradictions.

Insufficient preparation time

As discussed earlier, teachers' reported difficulty finding time to create good TEFA questions can be unpacked into three overlapping factors: lack of supporting curriculum materials, inadequate TEFA question design skills, and inadequate prep time. The first factor can be considered an incompleteness of the TEFA toolkit itself. By failing to provide curriculum materials alongside the technologies and techniques of TEFA, we forced teachers to adopt the additional role of curriculum designer. Thus, a shortcoming in the tool led to a conflict between it and the system's established division of labour: a secondary contradiction between elements of the system.

The second factor, teachers' insufficient skill at question design, can be viewed as a secondary contradiction between the subject (teacher) and the new tools (TEFA). Such a difficulty is inevitable any time new and nontrivial tools are introduced to an activity system.

The third factor, insufficient preparation time, indicates a structural flaw in the system. By providing teachers with very limited prep time, schools hinder pedagogic or curricular improvement of any kind, since any major change in teaching practice requires additional time and energy to plan, explore, and assimilate.

Technical difficulties

We see teachers' difficulties with the technology (including learning to operate it, teaching the students to work with it, and overcoming problems) as attributable to fairly straightforward secondary contradictions between the new tool (the classroom response system) and either the subject (the teacher's comfort and facility with the tool), the community (school technical support staff's knowledge and availability), the distribution of labor (tech staff's perception that supporting CRS use was not part of their mandate) or, occasionally, the object (students' interest in finding creative ways to misuse and abuse the technology).

Clash with teaching style

If a teacher's 'style' is his or her internalized and perhaps unconscious patterns of behaviour—that is, his or her comfort zone—then anything that perturbs the established system is likely to cause discomfort

and disequilibrium. Introducing TEFA into the classroom, first as an object and then as a tool, alters the system's dynamic, causing a secondary contradiction between the tool and subject (teacher). As other elements of the system adjust, such as the object (if students' behavior change in response to the use of TEFA), the rules (if TEFA's methods alter perceptions of what teaching and learning should 'look like'), and the distribution of labor (if the teacher's role shifts from authority to facilitator), a cascade of second-order contradictions between these elements and the subject may arise.

Incompatibility with subject or curriculum

A fundamental incompatibility between TEFA and the learning objectives of a class would constitute a secondary conflict between tool and desired outcome. For example, a highly skills-based class such as keyboarding has little conceptual content to ponder and discuss. We believe, however, that most reported incompatibilities were not with the content itself, but with the curriculum through which that content is traditionally taught. In these cases, we instead have a secondary contradiction between tools. (We don't call this a primary contradiction because it is not a dialectical 'dual nature' within one tool, but simply a clash between two different components of the system, even if they both fall on the same portion of the triangle diagram.)

Resolving the secondary contradictions

Most of the secondary contradictions just identified are transient, in the sense that they naturally abate with time: collections of questions accumulate, skills develop, feelings of disequilibrium recede, and clashing tools are adapted. Just as the quaternary contradiction of the 'TEFA as object' stage provided an impetus to either abandon TEFA or make it a useful tool, the collection of secondary contradictions in this stage drive further change. Within the TLT project, we have seen four different possible outcomes from this: rejection, accommodation, transformation, and provisional use.

These have blurry boundaries, and the first three form a sort of continuum. Rejection means that the teacher finds the secondary contradictions intolerable, or finds TEFA insufficiently beneficial to justify them, and either abandons TEFA or relegates it to an inconsequential role within his or her teaching. Accommodation means that the teacher adjusts and incorporates TEFA into his or her existing patterns of practice, enhancing but not deeply changing that practice. Transformation means that TEFA precipitates a dramatic and sweeping alteration of the teacher's practice and the entire classroom activity system. The fourth outcome, provisional use, is transient rather than stable: It means that the teacher's long-term relationship with TEFA has not yet been resolved, and the teacher continues to use it at some level while remaining ambivalent. Such an 'outcome' is unfortunately common in the context of a project like TLT, in which the teacher may feel socially obligated to continue 'exploring' TEFA for the duration of the project.

Stage 3: TEFA as transformed system

Rejection means that TEFA is no longer a meaningful part of the classroom activity system. Accommodation means that it remains a tool. Transformation, on the other hand, means that TEFA becomes more than just a tool: it expands to permeate the system, becoming deeply embedded in the rules, division of labour (roles), perceptions and behaviours of community members, identification of objects, and envisioning of outcomes.

To understand this, one must realize that TEFA is more than a collection of instructional tactics for using a classroom response system. It has three layers (Beatty & Gerace, 2009). The first is a vision of pedagogic objectives: 'to help students grow contextually robust, transferable conceptual ecologies that

are thoroughly reconciled with their experiences, perceptions, and prior understandings … by engaging students in extensive dialogical discourse about scientific ideas and their applications, set within the context of rich and challenging questions and problems … [and] to explicitly confront students' beliefs and attitudes, communicate high teacher expectations, and scaffold self-directed, self-regulated learning habits' (Beatty & Gerace 2009:7). The second layer is a set of core pedagogic principles. The third layer is an interlocking system of instructional tools and tactics. Although the majority of the TLT project's professional development time was devoted to tools and tactics, teachers were also engaged on the first two levels.

The TLT case studies indicate that the 'instructing | controlling' primary contradiction discussed above can either dissuade or motivate teacher's adoption of TEFA. The case for dissuasion is obvious: Teachers fear that students will misbehave within the apparently tolerant and inviting atmosphere of TEFA, or will cause TEFA to fail by refusing to participate meaningfully. The case for motivation is less obvious: TEFA has been designed to foster student engagement and investment, encouraging and scaffolding in many ways both overt and implicit the emergence of a student-active learning dynamic, subverting the instructing | controlling dichotomy. If we are correct in recognizing the primary contradiction of secondary education and in identifying the solution as transcending the dichotomy, then TEFA offers a pathway for achieving such transcendence. Teachers that chafe under the dichotomy may perceive this and be encouraged to take a 'leap of faith' in making wholesale changes to their practice.

> This semester, I did a lot of risk taking, a lot that paid off for me in the end. But for a long time it was, I was scared. 'Was this gonna work?' You know? …. I decided that maybe the teacher's role is at the back of the classroom, and not at the front. Maybe the students are to be the drivers, and not the teacher. And I tried that this year and it worked…. There's the whole idea of having students struggle through and sort of finding their own way, and by their own path. Um, I just thought that maybe we should try that. You know?…. [The students] are able to come up with their own problem sets, um; they go to the front of the board. If I am not there, they take over the entire class. I mean, I've had subs saying to me 'Wow, what a class you have!'…. They hooked up the SmartBoard and they, as a class, they had their classroom discussion.
>
> — participant b104, pedagogical perspectives interview, year 1 (emphasis by speaker)

When TEFA so thoroughly transforms the activity system of one teacher's classroom, it can cause tertiary contradictions between that system and the linked systems of other teachers' 'less culturally advanced' classrooms. TLT staff witnessed the beginnings of such tertiary contradictions at site B.

Summary and discussion

In this paper, we have explored the utility of cultural-historical activity theory (CHAT) as a lens for understanding the difficulties teachers face and the evolution their practice undergoes as they encounter TEFA, a novel, challenging pedagogy. We described the professional development programme and teachers' classroom teaching as two linked activity systems. Applying CHAT to TEFA professional development allowed us to connect it to our earlier co-evolution model. We found that the two connect well and complement each other. CHAT explicates how professional development and other circumstantial factors feature in the teacher change process, and the co-evolution model illuminates the temporal dimension of the system and the manner by which tensions within the system drive change, causing the teacher and his or her practice to co-evolve in an ongoing dialectical narrative. The conjunction of the two models suggests that teacher learning of TEFA can be an example of the expansive learning described in CHAT literature.

Applying CHAT to a teacher's classroom helped us identify the primary contradiction within secondary education: Students have a dual status as both objects of instruction and willful members of the community. This contradiction reverberates through the activity system, and can be understood as the root cause of many difficulties reported by teachers learning TEFA. Fear of exacerbating these difficulties can hinder teachers' adoption of TEFA, but hope of transcending the contradiction can motivate perseverance and risk-taking.

Building on these two applications of CHAT, we then suggested an activity-theoretic model for how a teacher's adoption of TEFA can proceed through three stages: TEFA as object, TEFA as tool, and TEFA as transformed system. In the first stage, the linked activity system of professional development 'injects' TEFA into the classroom activity system as an additional object, causing a quaternary contradiction between the systems. To resolve this contradiction, the teacher either rejects TEFA or learns to make it a useful tool. In the second stage, secondary contradictions between this new tool and other elements of the system (and, as changes propagate, between pairs of other elements) drive a teacher towards one of three possible resolutions: rejection, accommodation, or transformation. If the classroom activity system moves to transformation, tertiary contradictions between it and other activity systems in the school can arise and drive further change.

This paper is a theoretical exploration, and our three-stage model for teacher change and adoption of TEFA should remain suggestive and tentative until substantiated or contradicted by empirical data from other contexts. Nevertheless, we see promising implications in our work. One is that we might improve professional development by better anticipating and mitigating the difficulties a pedagogical innovation will encounter, and also by familiarizing teachers with the primary contradiction and the sequence of other contradictions they are likely to encounter when adopting it, in this way helping both teachers and facilitators address root causes rather than chasing symptoms. Another is that we might better reveal the ways in which many well-intentioned efforts to 'fix' educational systems in fact exacerbate problems by entrenching and inflaming, rather than transcending, the primary contradiction.

Acknowledgements

We are grateful to our colleagues in the Teacher Learning of Technology-Enhanced Formative Assessment project – our community in this little activity system – including William Leonard, William Gerace, Hyun Ju Lee, Robby Harris, Karen Tallman, and Karen St. Cyr, for many productive discussions and for their roles in project activity. Preparation of this manuscript and development of the ideas described have been supported in part by US National Science Foundation grants TPC-0456124 and TPC-1005652. Any opinions, findings, conclusions, and recommendations expressed are those of the authors and do not necessarily reflect the views of the NSF.

References

Beatty, I. D., & Gerace, W. J. 2009. Technology-Enhanced formative assessment: A research-based pedagogy for teaching science with classroom response technology. *Journal of Science Education and Technology* 18(2):146–162.

Beatty, I. D., Feldman, A., Leonard, W. J., Gerace, W. J., St. Cyr, K., Lee, H. et al. 2008, April 1. *Teacher learning of technology-enhanced formative assessment*. Paper presented at the Annual Conference of the National Association for Research in Science Teaching, Baltimore, MD.

Center for Activity Theory and Developmental Work Research (CATDWR). 2003. The activity system. Accessed 23 February 2009, from the University of Helsinki: http://www.edu.helsinki.fi/activity/pages/chatanddwr/activitysystem/

Cuban, L. 1993. *How teachers taught: Constancy and change in American classrooms, 1890–1990*. New York: Teachers College Press.

Dufresne, R. J., Gerace, W. J., Leonard, W. J., Mestre, J. P. & Wenk, L. 1996. Classtalk: A classroom communication system for active learning. *Journal of Computing in Higher Education* 7(2):3–47.

Engeström, Y. 1987. Learning by expanding: An activity-theoretical approach to developmental research. Accessed 1 March 2009, from http://lchc.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm

Engeström, Y. 2001. Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, *14*(1):133-156.

Feldman, A. 1996. Enhancing the practice of physics teachers: Mechanisms for the generation and sharing of knowledge and understanding in collaborative action research. *Journal of Research in Science Teaching*, 33(5):513–540.

Feldman, A. 2002. Multiple perspectives for the study of teaching: Knowledge, reason, social context and being. *Journal of Research in Science Teaching* 39(10):1032–1055.

Feldman, A. & Capobianco, B. M. 2008. Teacher learning of technology enhanced formative assessment. *Journal of Science Education and Technology* 17(1):82–99.

Fies, C. & Marshall, J. 2006. Classroom response systems: A review of the literature. *Journal of Science Education and Technology* 15(1):101–109.

Henning, E. 2008. Theoretical struggles in the zo-ped of research programmes. *Education as Change* 12(2):5–24.

Leont'ev, A.N. 1981. *The development of mind: Selected works of Aleksei Nikolaevich Leontyev*. Pacifica, CA: Marxists Internet Archive.

Loucks-Horsley, S. 1996. Professional development for science education: A critical and immediate challenge. In R. Bybee (Ed.), *National Standards & the Science Curriculum*. Kendall/Hunt.

Murphy, E. & Rodriguez-Manzanares, M.A. 2008. Using activity theory and its principle of contradictions to guide research in educational technology. *Australasian Journal of Educational Technology* 24(4):442–457.

Roth, W.M. & Lee, Y.J. 2007. Vygotsky's neglected legacy: Cultural-historical activity theory. *Review of Educational Research* 77(2):186–232.

Supovitz, J.A. & Turner, H.M. 2000. The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching* 37(9):963–980.

Vygotsky, L.S. 1978. *The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wertsch, J.V. 1991. *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Whitelaw, S., De Beer, J. & Henning, E. 2008. New teachers in a pseudocommunity of practitioners. *Education as Change* 12(2):25–40.

Yin, R. 2003. *Case study research: Design and methods (3rd ed.)*. Newbury Park, CA: Sage Publications.

Corresponding author

Ian D. Beatty
E-mail: idbeatty@uneg.edu