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The digital education revolution: New South Wales science teachers' response to laptop ubiquity

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Title: Laptop Ubiquity: A Case Study of Science Teachers' Response to the Digital Education Revolution

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Abstract

Since the introduction of laptop computers across Australia for all Year 9 students, teachers have sought to make meaningful use of the learning potential represented by the introduction. This study uses a lens of cultural historical activity theory to explore how teachers have responded to the ubiquitous presence of student laptop computers during the initial implementation. This paper reports a one-year case study of two highly qualified and experienced high school science teachers that considers their efforts to implement laptop computers in Year 9 and Year 10 science classes. The study shows that these teachers are committed to developing and delivering technology-rich lessons and furthering the learning potential represented by the computers in terms of engaging "21st century learners." There are, however, several tensions and contradictions that represent significant barriers to developing the learning potential and teachers' continued engagement with this activity system. These include: 1) classroom and school connectivity along with computer durability and availability for classroom activity; 2) student reluctance to engage with the computers as a learning tool amid generally low levels of cognitive engagement; and, 3) unanticipated changes to classroom management due to the laptop introduction. Now, more than two years into the introduction of laptop computers, teachers are still very much in a transition period from "before laptops" to "after laptops."

Background

In August, 2009, then-Minister of Education in New South Wales [NSW] Verity Firth announced that "students will be able to access more learning tools than ever before. They'll be more computer literate and in the long term more competitive in a global market" (Ministers Media Centre, 2009). The Minister was on hand as the first laptops were delivered to students at Fairvale High School in Sydney on August 26, 2009, and she laid out lofty goals that parallel national initiatives to provide all high school students with laptop computers (Commonwealth of Australia, 2009). As of February, 2012, the federally-funded, \$2.4 billion project called the ‘Digital Education Revolution’ [DER] has delivered 911.000 laptop computers to students currently in Years 9-12 across Australia to use for educational purposes across all of their subjects (Commonwealth of Australia, 2012).

In this cultural and historical context, classroom teachers became responsible for guiding students in using the laptops as tools for learning. It is thus reasonable to ask, as did Barowy and Jouper (2004), how are teachers managing and adapting to these conditions? Barowy and Jouper were looking more broadly at the uptake of educational technology, but the current study takes as its focus the significant educational change of the ubiquitous presence of laptop computers in the science classroom. The project reported here looks at a small piece of this issue as it explored how science teachers have implemented the use of laptop computers as learning tools in their classrooms. Teachers have responded to the introduction of laptop computers in a variety of ways, and the reported research draws from sociocultural perspectives of teachers’ activity in the classroom to gather and analyze observational and interview data. The state and national initiative of the Digital Education Revolution represents a major shift in educational policy, alongside a significant resource commitment, the implementation for which can be viewed at the level of the classroom and teachers’ goal-directed activity to develop the learning potential of the one-to-one laptop program.

One-to-One Laptop Programs

> A new environment of schooling has been emerging over several decades of the 20th Century, stimulated by a new economy, new technologies and new understanding about learning. In today’s interconnected, technology driven world, learning typically takes place in physical, virtual and remote places. It is an integrated, highly-technical environment in which learners learn. The new learning spaces incorporate technologies, engage the learner, creating new learning possibilities, enhancing achievements and extending interactions with local and global communities. (Australian Policy Online, 2011)

Moving into the 21st century, contemporary views on learning in schools include creating such environments for students to engage them in learning and prepare them for their lives after school. Placing laptop computers in the hands of learners is consistent with this view and part of a strategy by the Australian Government, through its Department of Education, Employment and Workplace Relations [DEEWR], to provide laptop computers and associated digital technologies to Australian schools to “prepare students for further education, training and to live and work in a digital world” (Commonwealth of Australia, 2011, para. 1). Interestingly, the current strategic plan that outlines goals and strategies for the national initiative of the one-to-one laptop program makes little mention of student achievement (DEEWR, 2008), even though the initiative purports to be about improving learning.

In a recent review of literature for the New South Wales Department of Education and Communities, Stavert (2010) found mixed results and much variation in student achievement after the introduction of several large-scale laptop computer projects around the world. Key to student success seemed to be the depth of the professional learning for teachers prior to the introduction. While the current study did not concern itself directly with teacher professional learning, measures of student success are generally taken from standardized test results. The Australian education system operates in a high-stakes standardized testing environment, and National tests are administered in Years 3, 5 and 7 and then High School Certificate exams are proctored in Year 12. These high stakes tests are a significant influence on teachers’ work, the use of which has been critiqued widely (Hardy & Boyle, 2011; Lingard & Renshaw, 2009; Ravitch, 2010). In Maine, USA, variation of student results after the introduction of a one-to-one laptop program was attributed directly to the uses to which the teachers put the laptop computers (Silvernail & Gritter, 2007). Teachers’ ability to use the computer as a pedagogical tool was a consequence of the quality of their professional learning. Other research has quantified levels of technology integration (Moersch, 1995), including eight levels ranging from non-use to refinement. The higher levels of Moersch’ scale parallel aspects of 21st century learning: students collaborate to solve problems; use digital technology seamlessly; their work is student-centered and focused on questions and inquiries of personal relevance. The teacher’s role at these higher levels of integration involves creating opportunities for experiential-based learning and utilizing an array of digital resources and technologies that engage students in complex thinking, problem-solving, reflection and production. But, as Howard (2009) points out, teachers perceive a risk related to technology implementation, more particularly to student achievement, as measured by standardized tests.

Digital technologies, including laptop computers, are intended to be tools for both students and teachers (DEEWR, 2008). As a new tool, the meaning of the laptop computers depends on the relationship between it and the prior culture of those who use it (Lin & Hatano, 2003). In other words, the existing set of tools, beliefs and practices are highly influential in the extent to which the activity system enables the teachers to negotiate this complexity.

Cultural Historical Activity Theory

Cultural-historical perspectives (Cole, 1991; Engeström & Miettenen, 1999; Vygotsky, 1978; Wertsch, 1985) of classroom activity include consideration of social, political, institutional and technological forces and how these are significant influences on teachers' work, and thus, cultural historical activity theory [CHAT] is a framework within which the current research can gain insight and understanding of teachers' approach to their work in the context of a significant educational change. Recently, CHAT has been used as a framework to understand design principles for educational technology (Amory, 2010), such as e-learning (Benson, Lawler, & Whitworth, 2008); to explore how learning technologies have changed practices in different subject areas (Scanlon & Issroff, 2005), including tensions and contradictions (Kahveci, Gilmer & Southerland, 2008); and, to explain and critique contextual details of the phenomena of educational technologies in various settings (Oliver, 2011). In the current paper, how teachers are implementing the educational technology of laptop computers can be explored through a macro lens of the activity system, and through a micro-analysis of aspects of the system. Identifying the activity system then allows for exploration of the tensions and contradictions that are part of this educational change. Internal contradictions can be of four types (Engeström, 1987; Roth, 2004): (1) within each constituent component of the activity system; (2) between components; (3) juxtaposition of the object of activity with the object of a more culturally advanced activity; or, (4) between each entity of a dominant activity and entity-producing neighboring activity.

Engeström's (1987) model of an activity system is shown in Figure 1. The top half of the triangle is Vygotsky's basic triangle (Cole, 1996; Cole & Engeström, 1993) that offers a graphic depiction and structure to theorize mediated action. Vygotsky was attempting to explain human development through the triangle, but the subject-object dialectic has also been applied to many other systems related to learning (see for example, Benson, Lawler, & Whitworth, 2008; Cole, 1985; Karpov, 2003; Wertsch, 1979). In Vygotsky's triangle, the subject could be an individual (or individuals) involved in an action that is mediated by social others, tools, artifacts or prior knowledge as directed toward some goal of the activity, which is the object of the system. Engeström (1987) built on Vygotsky's definitions to expand the triangle to include three other components that include the sociohistorical aspects of the activity system: *rules* are constraints or guidance to the subject about procedures or interactions that the community deems acceptable (Engeström, 1993); the *community* includes the subject and others who are members of a similarly oriented social group and motivated by the same object (Leont'ev, 1981); and, *division of labour* describes how work or tasks are shared within the community. As shown in the lines that crisscross Figure 1, in Engeström's (1987) activity system model each of the components of the system mediate for the subject and object, but also for each other. Within the activity system, tensions or contradictions can arise as attainment of the object is hampered or constrained by one or the other of the components of the system, and possibly creating conditions critical to the other components in the system. The components interact dynamically, and thus, exploring the tensions and contradictions offers insight to instabilities as well as resiliencies within the system, which is pertinent in the current study that explores a significant educational change.

INSERT FIGURE 1 ABOUT HERE

In the activity system explored in the current study, teachers are agents (Sewell, 1992) and thus, subjects of the system, and the activity of the system is captured in their goal-directed and motivated implementation of laptop computers in response to the NSW DER policy initiative. Teachers' individual and corporate motivations, goals and actions are cultural resources (Roth, Tobin, Elmesky, Carambo, McKnight, & Beers, 2004) and dynamic aspects of the system to be explored because these are the bases out of which teachers implement educational change (Evans, 1996).

As the teachers' goals and motivations mediate how the activity of laptop implementation is negotiated in the classroom, exploring other components of the system allows consideration of the dynamic context of the large-scale educational change. Teachers mediate rules established elsewhere, such as the Department of Education policy or Digital Education Revolution mandates, but also within the classroom and the school environment. Teachers are thus the important 'local factor' wherein the context of educational change is characterized and negotiated (Fullan, 2001). Further, teachers' positionalities within multiple communities, such as the local association of science teachers, groups of teacher colleagues at a school or in relation to technical support people are additional meditational influences that can be explored in the activity system. A community of teachers may share tasks on a number of levels, including collaborative lesson planning or individually developed lessons; administration work at the school level or in teacher professional associations; or, as allocated in responsibilities outlined in a Smarter Schools National Partnership (New South Wales Department of Education and Communities, 2010).

Assuming that components of the system interact dynamically allows investigation and analysis of the complex interactions and relationships that are themselves situated in social institutions and societal structures (Engeström & Miettenen, 1999). The activity system in the current study enables exploring tensions and contradictions as teachers mediate and negotiate the multiple facets of implementing the particular educational change of the introduction of laptop computers to their classrooms. The study asks *How have science teachers responded to the Digital Education Revolution NSW?*

Methodology

The goal of this research was to capture data that would enable us to examine the role of the laptop computers as a sociocultural artifact that was introduced into the research participants' activity setting. To fulfil this goal, following Yamagata-Lynch (2003), we used data collection methods that captured data in the three planes of analysis: community/institutional, interpersonal, personal (Rogoff, 1995, 1998). More particularly, we focused on the interpersonal plane, where the data collection methods were targeted to reveal the teachers' actions and perceptions of their actions in how they engaged students using the laptops as a pedagogical tool. Naturalistic research methods (Lincoln & Guba, 1985) were used, and further, we adopted a case study approach (Merriam, 1998; Stake, 1995). Data collection methods included document analysis, semi-structured interviews, classroom observations and individual interviews. We observed up to five lessons in each classroom over the 2010 school year.

Data Analysis

The study generated a rich body of data and analysis was not straightforward. As researchers, we experienced the study participants' activities over a school year, and thus, our personal involvement affected the data analysis process. This could be interpreted as a threat to validity. Rather, we acknowledge the subjective nature of both our positioning and interpretations in providing the context, identifying the issues addressed and a rationale for our use of activity theory as an analytic lens.

We began to identify an activity system by reading and rereading the data. We first looked chronologically through the data set, then more strategically through observation summaries and identified emerging themes. These were tested through rereading of the data set and thus we identified meaningful activities that we saw as prevalent through our data set. We took this historical approach in order to consider the development of the activity over the studied school year. Through this analysis, we iteratively worked to develop narratives that characterize aspects of the activity system and also identified tensions among the components of the activity system.

Research Participants and the Classroom Context

In selecting teachers to be part of the study, we wanted firstly, willing participants. Teachers who were willing to allow us to observe them teaching lessons when they used the laptop computers were recruited for the study according to NSW Department of Education and Communities protocols. We also wanted to be able to speak with the teachers before and after what were called 'laptop lessons' so as to unpack and debrief our observations. We held informal conversations with teachers who expressed interest in the study and used a snowball sampling method to find other science teachers who might be interested in participating. From these discussions, we identified our two case teachers, and through developing an understanding of their actions and perceptions, we could begin to understand the activity system.

The study took place in the southeast region of New South Wales, and the case involves two highly qualified and experienced high school teachers, Harriet and Mary (teacher and school names are pseudonyms), both of whom were assigned to their schools as high school science teachers. Both teachers have served their schools and school communities as technology consultants and have held leadership roles in the schools where they have worked. The teachers knew each other as colleagues but had not worked together in the same school during their teaching careers.

Harriet had worked at Northside High for more than 15 years, and often served the school as a Deputy Principal for varying lengths of time during each school year. The longest of her appointments (during the 2010 school year) in the role of Deputy Principal was three months, a time during which she continued to teach only one of her science classes (upper-level Year 10 Science) while a long-term casual teacher handled the rest of her classes. Even during this 3-month period, it was uncommon for her to be in the classroom teaching during the rotating block for Science 10, as she was called away to manage administrative responsibilities for the school. Harriet was an 'early adopter' of technology applications to teach science. For many years, she had actively sought opportunities to introduce technology tools to her science teaching. She had been instrumental in organizing a school-wide wireless network before the introduction of laptop computers from the DER, and the school had been heavily invested in desktop computer laboratories for many years (three computer labs that operated at 100% capacity). Harriet had attended all of the Department of Education-sponsored workshops and participated in discussions around the introduction of the laptops and the tools available therein. She also led professional learning workshops at Northside for her colleagues. Her focus was on facilitating a wider repertoire of computer-based lessons among the other teachers at Northside. Further, this was a cost-saving measure, as attendance at the Department-sponsored workshops involved fee payment and the engagement of a Casual Teacher, costs that were not possible for the entire teaching staff. When the first laptop computers arrived for Year 9 students in November, 2009, Harriet ran a 2-hour crash-course introductory workshop for students.

Mary was also a highly qualified and experienced science teacher who had recently been appointed to a technology support role at Southside, which had been named a Centre For Excellence [C4E] high school. C4E is a targeted state-wide program that has created 50 “sites which demonstrate, develop and share high quality teaching, leading to improved outcomes for students” (NSW Smarter Schools Partnerships, 2010). As a science head teacher, Mary had previously spent about 15 years at a neighbouring high school that was well-known as a technology school, recognized for its programming and adoption of digital technology in teaching and learning. In NSW, the C4E designation brings additional personnel and resources to support the initiative being promoted, and Mary’s appointment to Southside was intended to provide expertise and opportunity to a less-advantaged school so that it could benefit from having new staff and access to resources. In the case of Southside, the C4E is part of a National Partnerships program aimed to enhance technology implementation. Along with a second teacher whose role it was to coordinate implementation of the DER initiative, Mary was charged with working with the teaching staff at Southside to develop their skills at integrating technology in their classrooms and organize professional development seminars for teaching colleagues, across the subject areas. The C4E staff ran seminars each Thursday afternoon at Southside, and teachers in the school (or from neighbouring schools) were invited to attend. Mary and the support teacher regularly polled the teaching staff in an effort to develop targeted kinds of seminars and workshops that the teachers would find most useful. Mary also worked one-on-one with teachers to develop technology-rich lessons for any subject area. While this was Mary’s first year at Southside, her many years of teaching experience quickly became a valuable asset for the school. In an ironical twist, Mary was hired for a new role in the fourth term of the 2010 school year, and was reassigned to work at the Regional Office of the Department of Education. Because she was no longer in her own classroom, her involvement with the current study ended prematurely.

Both Harriet and Mary had earned Masters degrees (in Educational Administration and Science Education, respectively) and volunteered to be part of the current research out of their interests in implementing laptop computers in the classroom and educational technology more generally. They were also interested in contributing to a knowledge base that informs the implementation of one-to-one computing programs and effective integration of laptop computers in other classrooms, including science.

Characterizing the Activity System in the Study

Guided by our analytic lens in activity theory, we sought manifestations of the aspects of the activity system and interrelations across the components. Through this seeking we also identified a number of tensions and contradictions, thus our results presentation begins with characterizing the activity system and then moves to the more particular aspects of our analysis supported by data from our multiple sources.

Figure 2 represents an elaboration of Engeström's (1987) model of an activity system, as characterized in the current study. Our initial conceptualization was based in definitions from sociocultural theory, while Figure 2 incorporates our analysis and synthesis of aspects of the system in the current study. It is not possible to precisely characterize all aspects of a system in a small diagram, nor would it be possible to exhaustively describe all the aspects, as the system itself is dynamic (Roth, 2004; Wells, 2004).

INSERT FIGURE 2 ABOUT HERE

Our description here attempts to encompass this dynamism, as well as the interrelationships between aspects so as to provide our interpretive view of the system. Our descriptions include vignettes or examples from the data set.

The teachers' goal-directed and motivated activity throughout this study was aimed at engaging their students in meaningful learning activity utilizing the laptop computers (supported by associated software and other available technology). The teachers' efforts were mediated through each of the aspects of the system as the object of their actions but first and foremost, through their intentions to utilize the laptop computers to engage students and thus support learning. The laptops and peripheral digital communications technology represent tools or artifacts in the activity system we characterized in the current study. The NSW Department of Education and Communities [DEC] had pre-loaded an array of very sophisticated software programs on the computers before their delivery to the students, in addition to basic word processing, note-taking and data management programs. Both teachers' and students' access to these software programs were mediated by DEC policy regarding licensing and updating of the software, which could only be done by the Department's technicians. Rules operate in this system on multiple levels: policies applicable to the school, the teachers and the classroom; constraints of the physical plant of the school; but also expectations from the Department and the school principal.

An example of rules applied at the classroom level comes from Harriet, where she developed a routine in her class for when she wanted the students to attend to the front of the room in a whole group lesson or discussion. She asked the students to turn their computer screens toward her, or fold the top downward, so that their attention was not directed at the computer screen. Mary had no such routine and suggested during the initial interview that "making sure the kids are doing what they are supposed to do is one of the hardest things for teachers to check or manage."

The physical plant of the schools also constrained activities and thus framed rules in the system. Harriet's classroom had moveable tables and chairs in the main part of the classroom, along with fixed lab tables along one wall. Mary's science classrooms had fixed benches, all oriented in long rows facing the 'front' of the room, which is a typical (and traditional) orientation of lab benches in science classrooms. The ability to move tables and chairs around the room enabled certain types of actions in the classroom, both in terms of students interacting with each other, but also with the teacher and for teacher monitoring of student activity.

The physical plant as part of rules in the system also includes internet connectivity. At Southside High School, where the laptop computers were delivered before functional internet access was available in classrooms, installing a wireless network to the science wings in this older, cement-block building required individual hubs for each classroom in the block. This requirement was only realized after the students received their laptops late in Term 2 of 2010, and connectivity problems revealed the inadequacy of the installed network.

Expectations from both the Department of Education and local principals are part of the rules of the activity system. As suggested by Harriet during our initial interview, “our principal has been rigorous in making sure that we are going to have [the computers] to the point that he has asked teachers to fill in a pro forma about which lessons you used the laptop in.” While likely negotiable, in expressing the expectation that teachers would use the computers as much as possible, the principal operates in this context as part of the rules for this activity system.

The community in which the participating teachers operated extended outward to their teaching colleagues, both at the same school and in other schools, and also to technical support staff. Upgrades or repairs to the laptop computers were managed by Technical Support Officers at each school. At Southside High, student laptops were summoned by the technician (usually during class time) in bunches for software upgrades or servicing. This could mean that, for 2-3 weeks at a time, and one to three times per year, the laptops were unavailable to a classroom full of students. Teachers were not necessarily made aware of when the call-in schedule would affect their students, and scheduled maintenance and upgrades often took longer than expected. At Northside, individual student computers were on a schedule for maintenance and upgrading. This meant that in a given classroom, 6-8 students were without their computers because the technician had them. When the computers were returned, it was possible that some students in the classroom had different versions of software programs, different from other students, but also the teachers, whose personal computers may or may not be allowed to have the student versions of the software programs loaded. It could be argued that the technicians operated in a completely different activity system from the teachers (e.g. their activity was to service computers, not attend to student engagement or learning), but the technician role was not examined beyond the teachers’ encounters with the technicians’ work, mostly through their impact on students.

Division of labour refers to how tasks within the system are divided up and shared among members of the community, in particular, the teachers in the community. In the activity system for the current study, we observed that tasks could be considered more on the basis of who or what directs the learning, rather than on how the tasks are divided up. For example, both of our case teachers were highly experienced science teachers, who approached lesson planning with a desire to foster and motivate autonomous learning by students. Thus, the teachers developed learning activities to engage their students, actions that reflected their beliefs that students should take ownership of their learning. Both teachers were also involved with supporting their colleagues through running professional development workshops. Thus, they shared the work of teacher learning with their colleagues. Mary did this through her appointment as a C4E support teacher at Southside and Harriet did this as a workshop leader for her teacher colleagues at Northside.

Having briefly described the aspects of the activity system in the current research, we move now to a discussion of the tensions and contradictions arising from the conditions present in the system as a result of the components interacting.

Results and Discussion

Here, we present two lesson vignettes, and through these, view details of the activity system under study and then, elaborate three key tensions and contradictions that emerged out of the data set that we feel describe and illuminate the case teachers' responses to the Digital Education Revolution. The lesson vignettes illustrate the teachers' responses and our interpretations that inform our understanding of how these teachers are negotiating the educational change of the DER.

Two lesson vignettes

Harriet

Harriet invited us to her classroom when she specially designed a 'laptop lesson' for her upper-level Year 10 science students, which happened to be a day where about half of the students were attending Scripture class.[1] Harriet had responsibility for a number of Year 9 students whose teachers were otherwise engaged during this hour.

As the unusually small number of Year 10 students arrived for the day, Harriet projected a cartoon image on the classroom screen. The image portrayed a "Mouse vs. Elephant Celebrity Challenge," showing an elephant and a mouse falling from the sky. Students were requested to log on to their computers and the school's server so that they could access the internet and documents on the school's Moodle (Pukunui Technology, 2005) that Harriet had prepared for the lesson. Once all students had logged in, Harriet asked them to turn their computer screens towards the front of the room.

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[1] In NSW, scripture classes are optional and highly variable among public schools. At Northside, 1-hour, monthly (generally) lessons were convened by a local chaplain or community member, who guided the students in religious instruction. Approximately 60% of Northside's students attended these classes. Students who did not attend scripture classes were left under the supervision of the teacher whose class had been replaced for that hour, and in the class we observed, Harriet carried on with her regular program in spite of the small number of regular students present.

She asked the question, *Which one hits the ground first?* as an introduction to the day's activities and discussion around Newton's Laws of motion. Another cartoon image, of Galileo tossing computers off the top of the Leaning Tower of Pisa, began a class discussion about depicted inaccuracies or truth-challenges. Discussion led to Newton's Third Law, and the challenge that Harriet issued to her students: design and conduct an experiment, using the technology tools on the computer and any other available science lab equipment, to test Newton's Third Law.

Harriet then guided the students through a number of software tools available on the laptops. Reviewing earlier lessons with her students, Harriet presented the abbreviation, "C-M-S" as a heuristic for designing a fair test. In considering whether the elephant or the mouse would hit the ground first, Harriet asked, *What needs to be* ***C****hanged?* (e.g. variable, or object mass), *What needs to be* ***M****easured?* (e.g. time taken to hit the ground, or a record of the two objects hitting the ground, as in a digital image) and, *What needs to stay the* ***S****ame?* (e.g. the control, or invariant aspects). Harriet then demonstrated dropping two objects, using the CMS framework, asking students to offer ideas for each of the C-M-S points. We observed that no students recorded notes on any of the information covered in this introduction to the task, although most of the students were involved in the discussion. Harriet reminded students of the formula f=ma and then tasked them to write 100 words explaining if the objects would hit the ground at the same time. Bonus marks were offered if the explanation involved poetry.

In about five minutes, further class discussion began around a new series of questions. Harriet demonstrated the laptop's built-in video capability to capture object motion (e.g. falling) and then encouraged the students to work in groups of two or three to practice techniques they might use to conduct their experiments, including dropping objects from the second floor of the building. Students were observed to test ways to control the start/drop time, ways to orient the video camera (built-in to the laptop) and objects to be video-recorded. Students were also encouraged to try different software programs and tools, such as a single-frame advance for video playback. Harriet admitted to her students that she did not know all the nuances and capabilities of the programs, but offered encouragement for students to explore the programs and use them to design and conduct their experiments.

Mary

During this Year 9 lesson, Mary used the classroom's LAN connection to connect her personal laptop computer to the internet. As we saw with Harriet at Northside High, Mary at Southside likewise had no ‘spare’ computer available to her. She used her personal laptop to prepare lessons for her classes, and had installed the Clickview video she intended to show the class. The video illustrated the electromagnetic spectrum and Mary used this clip as a review of material that the class had been working with over the previous week. She connected the laptop to the classroom’s digital projector, but the system would not produce sufficient volume for the class to hear the video soundtrack. Mary spent several minutes attempting to troubleshoot the problem with the system volume, and eventually instructed the students to use their own laptops to access the video as well as additional lesson documents that she had previously loaded on the class Moodle site, and then to use headphones to listen to the video on their own computers. As the students began to log in to the Moodle through the school’s homepage, all of the students needed to initialize their Moodle accounts, since this was the first time they had attempted to access their individual accounts. Some students were able to log in without problems and retrieve the files Mary had loaded. Other students were able to log in, but could not open some of the files. Others could not log in at all. Mary instructed these students to get a fellow student to email the documents for the day’s lesson. Of those students who were able to access the Moodle files, several were unable to open the video clip on their laptop computers. Mary asked students to look on with their neighbors if they were unable to view the clip on their own computers. It seemed that each student had a different problem in accessing the files through the class Moodle, and each one of them asked Mary for assistance.

At this point Mary realized that she was not likely to be able to follow her original lesson plan with the video, and began teaching from her notes. She asked students to access the worksheet from the Internet (if they were able to log on). Student boredom was prevalent during this lesson and disinterest grew as Mary began teaching from her notes. Further, she walked around the classroom to ensure students were attending to the task. For those students who were able to access the worksheet from Moodle, Mary showed them how to load and save it into OneNote. As there were several students still unable to access the worksheet, Mary loaded it on to the board via the projector, and instructed the students to copy their answers into a separate OneNote document. Mary took the students through the first questions, then asked the students to work on the rest by themselves while she continued to try to fix connectivity issues for various students.

This series of problems in accessing the materials for the lesson took nearly one hour. Students were observed being frequently off-task, either playing on the Internet, if they could log on, or playing different games they had loaded on their computers. As the hour wound down, students who were unable to view the Moodle video clip were asked to view it at home before the next class meeting and take notes about what the video showed while completing the worksheet.

Mary was due to teach another section of Year 9 science after the morning break and having been unable to rectify the system audio issue (in the midst of dealing with 24 students having log-in problems), she tested the volume system in another science lab during the break and then exchanged this classroom for her own with the other teacher. This exchange was confirmed just before the scheduled start of the class. Moving two sets of students around to alternate rooms caused an additional degree of difficulty for Mary, although she was able to teach her original lesson plan with the second group of students.

Tensions and Contradictions

In this section, we outline and describe three tensions and contradictions, each of which manifest on Rogoff's (1995, 1998) three planes, although, as acknowledged by Rogoff, the planes are mutually constitutive, so cannot be considered separately. Summarizing the tensions and contradictions: a) a reliance on the connectivity required to utilize the technology means great potential for time wasted and student and teacher frustration; b) students remain passive with both the technology and the learning opportunity in the face of teacher commitment and persistence to foster engagement; and, c) revisions to classroom management as the technology tools necessarily mediate teacher lesson preparation and planning for instruction.

Classroom/school connectivity

This initial section considers classroom and school connectivity, as connectivity is a primary issue for teachers as they attempt to implement lessons using the laptop computers. Here, we consider connectivity as both student and teacher access to relevant hardware and software and internet or wireless networks. Classroom and school access to both the internet and reliable use of computers is an on-going challenge for teachers and students. Wireless networks are often inadequate to support a classroom full of laptops and their teacher. Computer durability remains an issue. Further, updating software on the laptops is time-consuming, rendering the technology unavailable for periods of time and/or unreliable at others.

The issue of connectivity becomes apparent upon computer startup for any lesson that involves the laptop computers. At Northside High, Harriet could never be sure how many of her students would be able to access the wireless network at the school from the science lab. The network had on-going reliability issues as well as dead spots in the room. This was also true across the school grounds. A further complication was that the upgraded wireless router for Harriet's science classroom could handle a maximum of 25 simultaneous users. The 26th student to log in would cause the system to lock up or crash. Rebooting the system and restarting all computers could easily consume 15-20 minutes of the 55-minute science block. Thus, Harriet regularly planned for an alternate, text-based, non-computer version of the laptop lesson.

From the vignette in Mary's classroom, the activity system represented by the technology-rich classroom environment presented numerous challenges to implementing the day's lesson: Mary had to be prepared for both classroom and student connectivity problems, and the potential for such problems to interfere with the lesson plan is great. Internet connectivity was but one of a variety of different connectivity problems, any of which had potential to completely disrupt the day's lesson. In the end, Mary scrapped the lesson she had planned, and shifted her goal for the lesson about midway through the hour. She later told us that in dealing with the multiple connection and log in issues, she adjusted her lesson goal to ensure every student could connect to the Moodle.

Connectivity problems, whether due to the physical plant of the school or emergent as a result of use become issues of planning for instruction, but they also point to a tension between using the technology as a learning tool and changes required to classroom management. Frequent connectivity issues and the flexibility needed to shift gears if/when hardware or software problems emerge, as they seem inevitably to do, means planning for implementation needs to allow for this dynamism. Its effects on student engagement are explored next and may be a significant factor in the generally low levels of cognitive engagement.

Student reluctance to engage with the computer as a learning tool

In the lesson vignettes presented earlier, we saw examples of technology-rich and engaging lessons designed by our case teachers based in their beliefs that these are motivating for students. The teachers made regular and substantial investments in preparing and implementing technology-rich lessons for their Years 9 and 10 science classes. Yet, we observed an overall reluctance by students to engage with the computers as a learning tool. And, according to the teachers, technology tools do not support higher levels of cognitive engagement even when the tasks are rich. At best, the students have more on-task time. At worst, they are bored, disengaged and resistant, sometimes belligerently so. As a rule, students are not self-directed or interested in elegant and highly interesting and demanding work on their laptops.

We suggest that there are several reasons for students' low levels of engagement. First, both teachers and students experienced immense frustration over the ongoing connectivity issues discussed earlier. There was always uncertainty about whether students (or teachers) would be able to connect to the internet or access the software needed for a particular lesson.

Second, at times the technology may only place low cognitive demand on the students. We observed lessons across a broad spectrum of technology use and it is clear that not every lesson can be highly engaging and utilize multiple resources, but using the internet for assignment work was pervasive. Commonly, students copy-and-pasted the answers to their teacher-designed worksheets or for their own notes in the OneNote software program. An example comes from another of Harriet's lessons at Northside, where she reviewed material that a Casual Teacher was to have covered the previous class meeting of the Year 9 science class, when Harriet had been called away to administrative duties. The worksheet Harriet had prepared asked the students to use the internet as a resource to identify and label parts of the human ear and ear canal. On her return to class, she began reviewing the student work from that day, projecting a copy of the worksheet on the whiteboard. She invited the students to identify the parts of the ear, a request that was met by silence as no students offered answers. But, they had all filled in the worksheet in class two days previously. Harriet reported later that she has learned that students will generally copy-and-paste answers from any internet site, often indiscriminately, and thus struggle to retain any of the information. She saw this simplistic approach by the students as indicative of a general reluctance to engage with the technology as a learning tool and benefit from the potential offered by the range of activities she could design using the available software programs on the computers.

While not a problem, per se, teachers and students need to learn to use new software programs. The NSW Department of Education and Training licensed a suite of programs for the laptop computers, most of which were new for both students and teachers. Frequently, the teachers would have to set aside time for the students to 'have a go' with the program. Interested students would spend time exploring the program, disinterested students would move off task, and others would be confused with the program and ask for help from the teacher. Teacher familiarity with the program was thus important, but the possible range of student responses meant teachers were faced with a 21st century classroom management issue: the need for both teachers and students to explore the resources before being able to use them as learning tools.

When the first laptops arrived, as our teachers reported, all students were initially enthusiastic about bringing their computers to class and were ready to follow the teacher's instructions for the day's activities. However, as the initial term and school year wore on, frequently students forgot their computers or resisted when the teacher asked them to log on. We suggest that this is a consequence of a 'novelty effect' and Harriet felt that this was particularly the case for students who were lower-level learners more generally. And, she felt this demonstrated their general reluctance to engage with the computer as a learning tool. We draw a parallel to research literature on the need to reduce novelty in a highly stimulating environment (Anderson & Lucas, 1997; Kubota & Olstad, 1991) because high novelty may impede cognitive engagement. The initial high novelty of the laptops in schools may have impeded student access to the laptops as learning tools and thus, teachers may need to focus on this aspect of the educational change represented by the introduction of the laptops, particularly as new rollouts begin in subsequent years.

Changes to Classroom Management

Classroom management is significantly different in an environment where all students are working on laptop computer as computer lessons often involve less teacher-directed activity. Both case teachers noted changes to their pre-laptop management techniques and realized implications for their pedagogy in implementing laptop use in the classroom. This appeared as a tension for the teachers' practice as they negotiated new management strategies during the beginning stages of implementing lessons using the laptop computers. With more student-directed or independent work time, it is easy for students to be off task without the teacher being aware of this, since computer screens may face the opposite direction. And, the typical structure of a traditional science classroom, such as Mary's, means the students sit at fixed benches or at tables oriented toward the 'front' of the room. In response to this problem, Harriet had developed a routine in her classroom that students would turn their screens down or around to face her when she wanted whole class attention.

Another aspect of classroom management involved submission of assignments. To submit work, students would often be asked to email a document to the teacher. In many cases, the files were too large to send or receive via the school's email program. Compressing documents or files was possible, but server capacity and connectivity (at home, for example) were then required. Thus, managing 21st century homework adds a layer to the marking portion of teachers' work. To resolve related issues, students saved their work on a USB thumb drive and handed this in.

We noted 'regular' disruptions to classroom activity too. Both of our participating teachers' classrooms had interruptions from students moving in and out, notes arriving from the office or intercom requests for students or information. As we saw in the vignette, Mary also moved her second class of students to another classroom to accommodate the digital technologies that had not operated as expected in her regular classroom. At Harriet's school, students needed to move around the room or even outside the room to find a wireless signal. Challenging the assumption that more technology is better, Mary suggested that, "the kids like the [technology], but they don't like it all the time." Thus, classroom management must accommodate a range of activities, some that include the use of digital technologies and some that do not. Given the instability of some of the hardware and software (which may reflect on-going growing pains), teachers must manage the challenge of unanticipated problems.

Implications for Science Teaching and Learning

Having noted tensions and contradictions in the activity system under study in this research, we turn to a discussion of implications for science teaching. We consider conditions for facilitating implementation of the one-to-one laptop program and then move on to challenges yet to come.

Teacher persistence

Teacher persistence is absolutely necessary for implementing the one-to-one laptop program. Our two case teachers were extremely committed to making the technology work, and on some occasions abandoned their lesson plans and spent the class fixing connectivity and log-on issues. What if teachers generally are not as committed as these two case teachers? Aside from the issue of making the technology work, the laptops have added many layers to what teachers need to plan for and manage. Thus, classroom management is different with computers, becoming even more difficult when some students do not have their computers or do not bring them to class.

Teacher knowledge and engagement

In addition to persistence, teachers need extensive knowledge and commitment to quality teaching. We observed that both teachers developed a technology rich-lesson alongside a non-technology-based back-up lesson in case there were laptop or connectivity issues. We believe their ability to do this was a function of their rich experience as science teachers, who had vast resources to draw from in lesson design and teaching methods. Even as we saw a return to teacher-directed pedagogy, particularly when a Casual Teacher was running the class for a day or failure of technical systems, we believe the case teachers' commitments reflect their values in moving their students toward 21st century learning, which assumes a less teacher-centered pedagogy and a stronger inquiry approach: "inquiry oriented teachers deployed technology to support and expand enquiry; more traditional teachers likewise used the technology according to their values, in conducting a teacher centred classroom" (Drayton, Falk, Stroud, Hobbs, & Hammerman, 2010, p. 48). In the case of our teachers, their values may have manifest in how alternate plans were effected. And, as we noted, both of our case teachers, were keen early adopters of technology, which we believe facilitated their sometimes difficult negotiations of the activity system under study here.

On-going implementation

The current study completed its observations as the 2010 school year drew to a close, but research literature points to issues that arise as implementation and normalization proceeds. During the third year of implementation, according to Newhouse (2008), it can be expected that computers will break down with increasing frequency. Additionally, complaints about battery life emerge. The natural attrition rate of computers as they aged, as well as the need for updates and upgrades, were also reasons cited for the need for ongoing technical support (Lei, 2010).

As the NSW DER laptop rollout continues, this suggests that there will be issues for on-going implementation. Problems with battery life and computer longevity are already emerging. In order for the implementation to be successful on a longer time frame, a stronger community connection needs to be made and maintained. For example, it would extremely beneficial if the technicians updating and fixing the computer either aligned better with the teacher's schedule, or at least informed the teachers in advance which computers they would be taking. This would enable to teachers to plan more efficiently for their lessons, and around the availability.

While this study did not examine students' technology proficiency, there is an underlying assumption of such, which requires a shift toward laptop pedagogy and a corresponding student shift from technology proficiency (e.g. learning about the technology) to learning with the technology.

Following Lin and Hatano (2003), these are the kinds of changes that happen at the interpersonal and community levels, and when they do, the educational change that is the laptop computer introduction through the Digital Education Revolution will push high school teachers and students toward 21st century learning.

Conclusion

In this study, we explored how the case teachers have responded to the ubiquitous presence of laptop computers and associated digital technology and how these tools have been utilized to encourage student engagement to learn science. Activity theory encourages a view that action(s) is/are transformative, and thus hopeful (Roth, 2004). But, as we have seen, despite highly engaging and rich learning opportunities that were created by the teachers, it is not evident that students take up these opportunities in meaningful ways. It will be important to develop ways and means of supporting students to utilize the technology as a learning tool.

The two teachers in our case study are early adopters AND keen participants. They are not likely to be representative of the general teaching population, a fact that needs investigation to consider the wider impact of the DER on teachers. Both of our case teachers were open to exploring the possibilities presented by the diversity of programs and tools available on the laptops, but they also developed rich tasks where the students could conduct their own explorations of science concepts and were very persistent in working around technical issues. With their intentions for technology-rich lessons, both Harriet and Mary used a variety of technology tools on the laptop computers, common science lab equipment, open-source information and used these to design open-ended tasks that encouraged students to utilize the rich possibilities of the technology.

Our case teachers could readily be considered leaders in technology implementation, and as Anderson and Dexter (2005) suggest, this leadership is key to successful school-level implementation of new educational technology. Given the enormous commitment by national and state governments in Australia to the Digital Education Revolution, it is important to consider the process of how the laptop computers have been adopted by classroom teachers, and further, how the laptop as a tool has impacted student learning. The latter issue is beyond the scope of this study. But, commentary on how teachers have engaged the laptops as a learning tool is an equally important question, since as this study shows, teachers are utilizing the technology and changing how they plan for and deliver instruction. Some of these changes are a direct consequence of the DER laptop introduction but there are also unintended consequences of policy change that forces teacher change. As Holcomb (2009) notes, "it is therefore critical for schools to understand that simply providing each student with a laptop is not enough. How teachers choose to use the laptops is very important" (p. 52). This small study explored how teachers are negotiating this high-level activity system across several planes of action. Developing understanding of the issues that teachers face in implementing laptop use thus allows critical consideration of the potential suggested by the Education Minister that the tool represented by the laptop is in fact equipping our students to be 21st century learners. In the case of the DER NSW, classroom teachers are both political and educational means to the educational end of policy implementation. This study has shown that teachers have had to make significant changes to their pedagogical and managerial approaches, while dealing with frustration, in relation to students' access to the laptop computers as both direct and indirect consequences of the policy change represented by the Digital Education Revolution.

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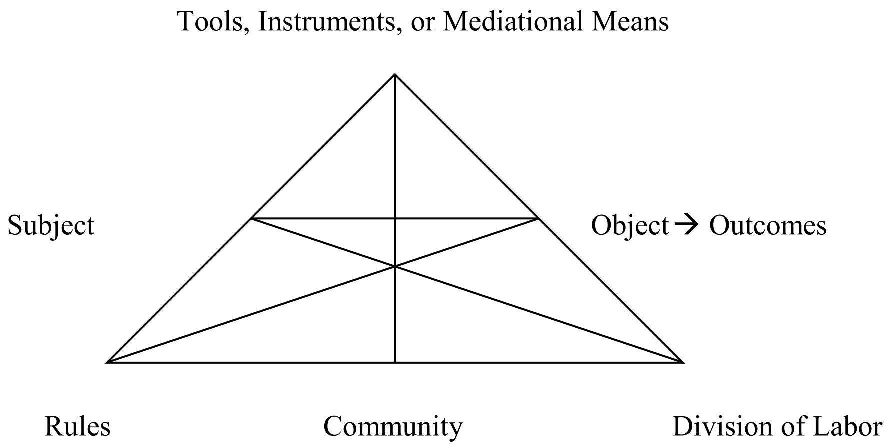

Figure 1. Activity System (modeled after Engeström, 1987)

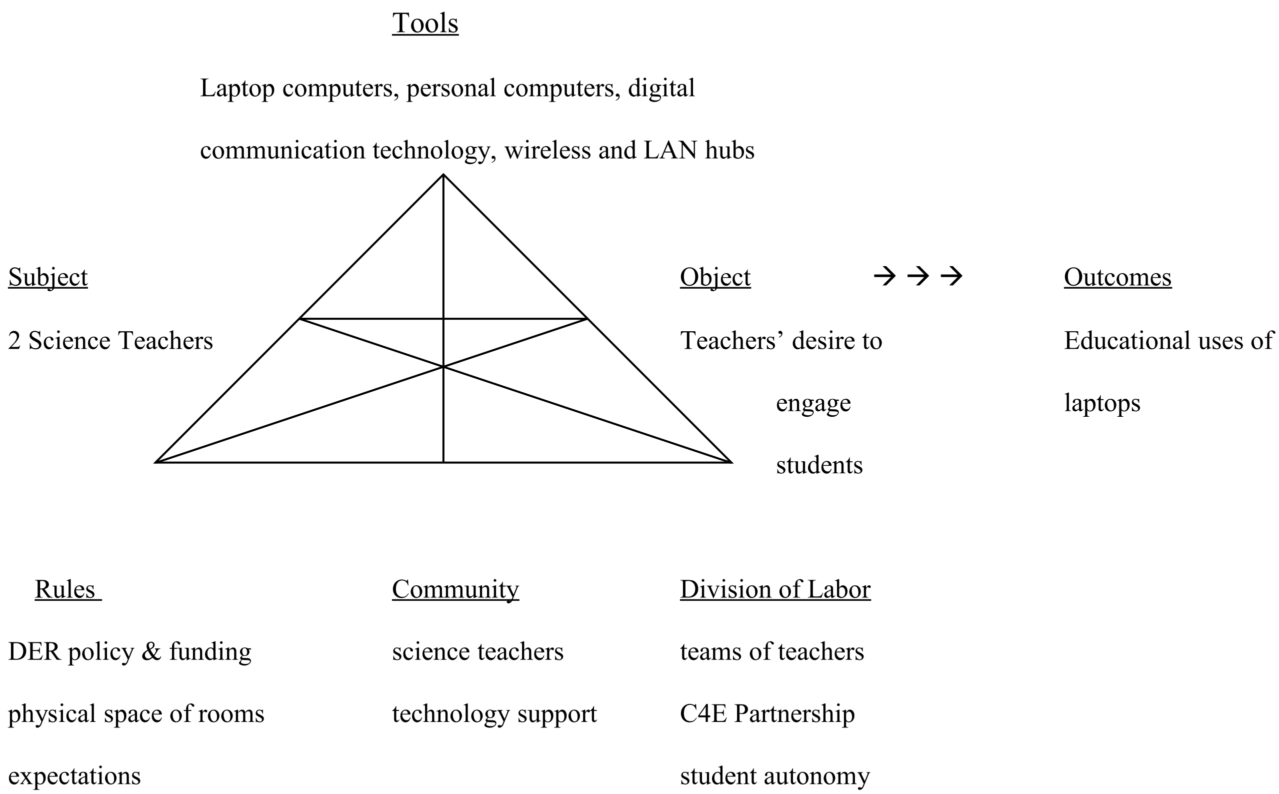

Figure 2. Characterizing the Activity System in the Study