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Science teachers' response to the Digital Education Revolution

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Abstract
We report a case study of two highly qualified science teachers as they implemented laptop computers in their Years 9 and 10 science classes at the beginning of the 'Digital Education Revolution,' Australia's national one-to-one laptop program initiated in 2009. When a large-scale investment is made in a significant educational change, it is important to consider teachers perspectives and responses to such change and we draw from sociocultural perspectives for our analysis. Through interviews and classroom observations, our interpretive analysis identified four key tensions and contradictions. These include the following: (1) barriers to innovative science teaching; (2) maintaining classroom and school connectivity; (3) teacher versus student expectations; and (4) changes to classroom management. Analysis leads to implications for the future of this and similar programs. The study shows that while these two teachers were committed to developing and delivering technology-rich science lessons, there were many factors that challenge how the implementation progressed. The findings from this study have implications for the continued engagement of teachers in this and other jurisdictions considering the introduction of one-to-one laptop programs.

Keywords
revolution, digital, response, teachers, education, science

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Introduction

A contemporary view on learning in schools places value on technology-rich environments to engage students in "21st century learning" to prepare them for life after school (Scanlon and Issroff 2005; Zucker and McGhee 2005). According to Wagner (2010), 21st century learning includes critical thinking and problem-solving; collaboration across networks; agility and adaptability; initiative and entrepreneurialism; effective oral and written communication; accessing and analyzing information; and, curiosity and imagination. These are high-level learning behaviors and skills that depend on the accessibility of Web 2.0 technology tools as well as teacher knowledge and pedagogies that develop the potential offered in a technology-rich environment.

At the turn of the 21st century, many government jurisdictions introduced one-to-one computing initiatives, aiming to provide laptops as a means to drive educational change to develop the kinds of learning behaviors needed in the 21st century (see for example, Silvernail 2008; Silvernail and Gritter 2007; Warshauer 2006; Warshauer and Grimes 2005; Zucker and Hug 2008; Zucker and Light 2009). The availability of digital technologies is particularly relevant for science learning in schools (Jones and Issroff 2007; Linn and Eylon 2011) because increased accessibility allows students to access science information at any time and supports different types of science learning (DEEWR 2008; Traxler 2010; Zucker and McGhee 2005). Further, in New South Wales, Australia, the Science K-10 curriculum (NSW Board of Studies, 1993, 2012) incorporates science and technology as a Key Learning Area.

One-to-One Laptop Programs

Early initiatives, such as the one-to-one laptop program in Henrico County (Virginia, USA) aimed to "provide our students with 21st Century tools and learning experiences that reflect preparations for today's world" (HCPS Technology Plan 2002-2005, cited in Zucker and McGhee 2005, p. 2). Starting in 2002, Henrico County provided every student in Grades 7 and 8 with a laptop computer (Silvernail and Lane 2004).

Maine's State Education Commissioner announced a similar focus: "laptops are essential to successful 21st century classrooms and schools….Using technology in this way helps prepare our students for the jobs of today and

tomorrow, and are in line with President Obama's challenge to build 21st century classrooms" (Maine Department of Education 2009, para. 7). Maine's state-wide program was intended to drive large-scale educational change through access to technology. Other jurisdictions have supplied laptops on a smaller scale, with more modest aims.

The Scottish Executive Education Department began one-to-one laptop projects in two schools (one primary and one secondary) in 2000: "The laptops provided the teachers with the means to access and use computers in their daily teaching and to be flexible in their presentation of materials to pupils" (Simpson and Payne 2004). The Scottish initiative was intended as a pilot to explore feasibility, value and conditions for other, larger-scale projects. Simpson and Payne reported a number of classroom level challenges, even with the small scale of the initiative, particularly at the high school level where traditional teaching approaches were only minimally adjusted to accommodate the new computers. Further, teacher competence (before the laptops arrived) and effective collaboration between teachers were key indicators for successful integration of the technology into classroom activities.

Other jurisdictions have focused on student improvement in particular subject areas through one-to-one laptop programs. For example, the Fullerton (California) school district issued computers to Grades 3-7 students in three schools with the explicit aim to improve writing skills (Warshauer and Grimes 2005). Other programs targeted individual schools, such as the Denver Science and Technology School, a charter school that already emphasized educational technology across the school prior to the introduction of laptops in 2007. The school environment became even better resourced when Hewlett Packard supplied the school with $1million worth of computers and associated technology (Zucker and Hug 2007). Reports from this school demonstrate the wide potential of one-to-one laptop programs for 21st century learning, given appropriate conditions to support high-level, effective implementation (Zucker and Hug 2008; Zucker and King 2009; Zucker and Light 2009).

Zucker and colleagues reported the teacher's role during effective integration involved creating opportunities for experiential-based learning and utilizing an array of digital resources and technologies to engage students in complex thinking, problem-solving, reflection and production. Teachers' abilities to use the computers as a pedagogical tool was a consequence of the quality of their professional learning. This has been a common theme through research reports on one-to-one laptop programs (Klieger, Ben-Hur and Bar-Yossef, 2010). In each of the jurisdictions cited by Klieger et al., the depth of the professional learning for teachers prior to the introduction of laptops was key to improving student results. Student achievement in large-scale laptop programs was the focus of a

recent literature review for the New South Wales Department of Education and Communities (Stavert 2010). The review described much variation in student achievement after large-scale laptops projects were introduced around the world, and this variation reflects, to some extent, the type of testing environment into which the laptop was introduced.

Australia introduced a one-to-one laptop program along with associated digital technologies to "prepare students for further education, training and to live and work in a digital world" (Commonwealth of Australia 2011, para. 1). Figure 1 provides an overview of the Digital Education Revolution [DER] Priorities and Timeframes, and suggests the complexity of the federally-funded, $2.4billion program.[1] As of February 2012, the program had delivered 911,000 laptop computers to each cohort of Year 9 students across Australia to use for educational purposes across all of their subjects (Commonwealth of Australia 2012). The laptops arrived at the schools

INSERT FIGURE 1 ABOUT HERE

Figure 1. Overview of DER implementation (DEEWR, 2008, p. 10)

preloaded with a suite of software programs, and schools gained access to additional educational technology, including software, wireless networks and interactive whiteboards, as well as technology support and professional learning for teachers. Implementation of the laptop program proceeded differently across the country because education decisions are made at the state and territory level. Teachers work at the intersection of the availability of new classroom technologies and students' learning, thus how teachers respond to the introduction of new technology impacts on several levels: classroom practice, policy implementation, the uptake of the technology and ultimately, student learning. The current study uses a case study approach involving two experienced science teachers to ask the research question: *How have science teachers responded to the Digital Education Revolution?* Subsidiary questions include: how have the teachers utilized the increased access to digital technologies, and how have their teaching practices changed? And, What are the challenges and tensions that they have faced in dealing with laptop ubiquity?

[1] The current study is not an evaluation of the DER program, however, interested readers are invited to access the formal reports from the research group that has conducted yearly stages in a formal evaluation (Howard and Carcellor 2010; Howard, Thurtell and Gigliotti 2012).

Theoretical Perspectives

The current paper is based in sociocultural perspectives of teaching and learning. We assume that teachers' individual and corporate motivations, goals and actions are dynamic aspects of a system of activity and at the same time, teachers are cultural resources (Roth et al. 2004) who implement educational change (Evans 1996). Teachers are agents in the activity system of a large-scale educational change and their actions in implementing the laptop program occur at the local level of the particularity of their schools and classrooms and the wider context of schooling and policy. Through observations and interviews, we interpret the case teachers' perspectives on and responses to the laptop introduction, which help us to understand how the process of implementation was enacted, how classroom pedagogy adapted to the introduction and how challenges during the introductory period were navigated. This is valuable information as new technologies are developed and translated for classroom use.

Methods

This research used an instrumental case study approach (Merriam 1998; Stake 1995) in seeking the two case teachers' responses to the initiation of the Digital Education Revolution (NSW Department of Education and Communities 2011). The case study approach aligns with our purpose for the paper to seek in-depth teacher perspectives. Data collection methods included both semi-structured and informal interviews with each teacher; classroom observations, where we sought to gain perspective on how the teachers' goals and motivations played out in terms of their teaching; and document analysis (NSW and Commonwealth of Australia policy documents, media reports, school level policies). We observed up to six lessons in the classrooms of two science teachers as the laptops were being introduced to their schools and held several interviews with each teacher over Terms 2 and 3 of the 2010 school year. The research design was reviewed and approved by the university human research ethics board and both case teachers provided written consent for their participation in the study.

Our initial interviews with our two case teachers were wide-ranging as we asked them about their teaching contexts such as the current state of technology in their schools and classrooms; their understandings of the policy framework for initiating the introduction; and their perspectives on science teaching and technology use. We also asked about their teaching backgrounds and goals, interests and motivations as the basis for teaching science. These are woven through the results discussion. We were invited to observe classes where the laptops were being used for

learning activities and held either pre- or post- interview discussions with the teachers about the lessons. We timed these interviews either before or after the 'laptop lessons' as the teacher's schedule allowed. During these discussions, we asked the teachers to comment on goals and plans for that particular lesson, including what was expected or noticed as challenging, or sought clarification about something we observed. The interviews and observations were conducted together by the first two authors. During the observations, we each kept a running sheet to record on-going activity in the classroom, in particular what the teacher was doing at a given time, what the students were doing and any other details of the classroom activity that seemed pertinent to enable characterization of the activity system for the research. These sheets constituted field notes that were then collated and summarized to inform subsequent interviews with the teacher and our further analysis. In some cases, the pre-lesson interview informed our observations, while in others, we shared our observations with the teacher as a means for teacher reflection on the lesson we had just observed.

In addition to field notes and running sheets from observations, our data set included policy documents and interview transcripts, which we co-analyzed using an interpretive approach (Schwandt 2003). We scanned and rescanned the data and sought to characterize the teachers' actions and perspectives as they implemented lessons with the laptops, which were viewed as their pedagogical response to the mandate of the Digital Education Revolution.

Data Analysis

Through interpretive analysis (Schwandt 2003) of interview transcripts, observations and documents, we gathered teachers' perspectives on the process of implementation, including goals, motivations and challenges. Analysis of technology introduction at the level of teacher perceptions is unusual in the research literature. In our analysis process, which we conducted collaboratively, we first looked chronologically through the data set, then more strategically through observation summaries and interview records to identify emerging themes. These were refined through rereading the data set and then revised as we returned to the classrooms and conducted further observations and interviews. We took this historical approach in order to probe the teachers' experiences of the introduction and initial stages of implementation of the laptop computers into their high school science classrooms. The teachers' perspectives are reflected through this synthesis, and to illustrate the cases, we chose one lesson from each teacher that exemplified the observed 'laptop lessons.' We developed these into a vignette from field notes and interviews.

The vignettes reveal the teachers' key intentions, how they faced tensions and contradictions manifest in their classroom, and further, offer a window into the dynamism of the classroom environment when teaching with the newly introduced laptop computers.

Results

The remainder of this paper is presented in four sections. In the first section, we characterize our two case teachers. Second, we present two laptop lesson vignettes to contextualize the teachers' approaches to laptop use. Third, we present a discussion based in our thematic analysis of four key tensions and contradictions that describe and illuminate the case teachers' perspectives on and responses to the Digital Education Revolution. And finally, we conclude with implications for science teaching and learning. Pseudonyms are used throughout.

The Case Teachers

Teachers who were willing to allow us to observe them teaching laptop lessons 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 these lessons so as to unpack and debrief our observations. We approached interested teachers informally through a regional meeting for science teachers and used a snowball sampling method to find other science teachers who might be interested in participating. From these discussions, Harriet and Mary became our case teachers.

Harriet

Harriet was in her late 40s at the time of the research, had taught at Northside High for more than 15 years, and often served as the school's relieving Deputy Principal. She had lived in the catchment area for Northside High for many years. The longest of her appointments in the role of Deputy Principal (during the 2010 school year, when this research took place) was three months, a time during which she continued to teach only one of her science classes (upper-level Year 10 Science, students aged 15-16) while a long-term Casual Teacher handled the remainder of her classes.

Harriet was an 'early adopter' of technology for teaching science. When asked about the school's goals for educational technology, Harriet offered:

> Up until the laptops came in, up until we knew that every kid was going to get a laptop, our goal was to make the school more technological. We installed a wireless network. Before we had the supplied one we had a wired network. A lot of our budget was spent making sure we had technology, so [the laptop introduction] wasn't a big change, except that we didn't have to spend lots of money buying computers now because the kids have all got their own, so we were able to direct our budget (that would have gone to computers) to buy interactive whiteboards and that sort of thing. (Harriet, interview, April 15, 2010)

The school had been heavily invested in desktop computer laboratories for many years (three computer labs that routinely operated at 100% capacity). Harriet had also attended all of the Department of Education-sponsored laptop workshops and participated in discussions around the introduction of the laptops and the tools available therein. Further, Harriet's attendance at these workshops was a cost-saving measure, as, registering for the Department-sponsored workshops required fee payment and the employment of a Casual Teacher, costs that made whole-school attendance prohibitive. Following a 'teach-the-teacher' model, she returned to Northside to lead professional learning workshops for her colleagues. These workshops focused on facilitating a wider repertoire of computer-based lessons. Harriet also ran a crash-course introduction to the laptop for Year 9 students when the first computers started arriving at Northside at the end of the 2009 school year.

Mary

Our second case teacher, Mary was of similar age to Harriet, and was also a highly qualified and experienced science teacher. She lived a considerable distance away from Southside High, commuting roughly 50 minutes to work. She had recently been appointed to a technology support role at Southside High, which had been named a Centre For Excellence [C4E] school. C4E was a targeted state-wide program that created 50 "sites which demonstrate, develop and share high quality teaching, leading to improved outcomes for students" (NSW Department of Education and Training 2010). As a science Head Teacher, Mary had previously spent about 15 years at a neighbouring high school that had been recognized for its programming and adoption of digital technology in teaching and learning. In NSW, the C4E designation brings additional resources and personnel to support the

particular initiative, and Mary's appointment to Southside was part of the 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 supporting the teaching staff at Southside to develop their skills at integrating technology in their classrooms and organizing professional development seminars across subject areas. Mary and her C4E colleague ran seminars each Thursday afternoon for teachers at Southside and neighbouring schools. Mary and the support teacher regularly polled the teaching staff so as to develop targeted seminars and workshops. Mary also worked one-on-one with teachers to develop technology-rich lessons for any subject area. 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 working in a classroom, her involvement in the research ended prematurely.

Both Harriet and Mary were certified as Professional Teachers in the State and 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 for teaching and learning in science 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.

Lesson Vignettes

These lesson vignettes were chosen to illustrate the case teachers' responses to the new and ubiquitous presence of laptop computers. They include many of the challenges they negotiated in order to adapt their classroom practices to include the laptop computers and serve as a basis for later discussion in this paper.

Harriet

The vignette is from a lesson in Harriet's upper-level Year 10 Science class. In the current science unit, the class was studying Newton's Laws and the lesson we observed involved review and reinforcement of prior lessons, including the concept of acceleration, which was further developed the following week.

As the Year 10 students arrived for the class, 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. Harriet asked the students to log on to their computers and the school's server to access the internet and documents on the school's Moodle. Once all students had logged in, and to gain students' attention, Harriet also asked them to turn their computer screens towards her at the front of the room. She asked the question, *Which one hits the ground first?* as an introduction to the day's activities. Another cartoon image of Galileo tossing computers off the top of the Leaning Tower of Pisa began a class discussion about depicted truth-challenges or scientific inaccuracies. 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 students through a number of software tools available on the laptops. Reviewing earlier lessons on designing a fair test, Harriet presented the heuristic, "C-M-S." In considering whether the elephant or the mouse would hit the ground first, Harriet asked, *What needs to be **C**hanged?* (e.g. the 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) and, *What needs to stay the **S**ame?* (e.g. the control, or invariant aspects of the test or experiment). Harriet then demonstrated dropping two objects, and using the CMS framework, asked students to offer ideas for each of the CMS points. We observed that no students recorded notes on any of the information covered in this introduction to the task, although most students contributed to the discussion. Harriet reminded students of the formula f=ma (force = mass x acceleration) and then tasked them to write 100 words speculating and explaining if the objects would hit the ground at the same time. In a creative twist, Harriet offered bonus marks if the explanation involved poetry.

After about five minutes, further class discussion began around a new series of questions. Harriet demonstrated the laptop's built-in video capability to capture free-fall motion and then encouraged the students to work in groups of two or three to practice techniques for recording free-fall motion. Students tested ways to regulate the start/drop time; ways to orient the built-in video camera; and made choices about objects to test. 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 encouraged them to explore the programs to design and conduct their experiments. Designing and carrying out the experiments were the focus of subsequent lessons.

Mary

During this Year 9 lesson, Mary used the classroom's Local Area Network connection to link her personal laptop computer to the internet. Similar to Harriet at Northside, Southside teachers were not issued DER computers. Mary typically began her classes with a whole-group focus, in a teacher-directed style and moved in and out of guided activities. In this lesson, Mary intended to use her personal laptop to show a ClickView video[2] illustrating the electromagnetic spectrum to review class material from the previous week. The video had also been loaded on the class Moodle site. She connected her laptop to the classroom's digital projector, but the system produced insufficient volume for the soundtrack. Mary spent several minutes attempting to troubleshoot the system volume problem, and eventually instructed the students to use their own laptops to access the video and use headphones to listen to the video on their own computers. She also drew their attention to additional lesson documents on the class Moodle.

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 them 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. Mary asked students to look on with their neighbours 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.

Mary's original lesson plan with the video became unworkable and she then instructed the class: "We're going back to an old-fashioned style of teaching—with a textbook" whereby she began lecturing from her notes. She asked students to access the notes skeleton from the Moodle (if they were able to log on) and walked around the classroom to monitor that students were recording information on the worksheet. For those students who were able to access the worksheet from Moodle, Mary showed them how to load and save it into OneNote (Microsoft, 2013). As there were several students still unable to access the worksheet, Mary loaded it for the class to view via the digital projector, and instructed the students to copy their answers into a separate OneNote document. Mary guided

[2] ClickView (2012) supplies web-based educational videos on a wide range of science (and other) topics for classroom use.

the students through the first questions and asked them to work through the remainder while she continued to troubleshoot connectivity issues for several students.

This series of problems in accessing the materials for the lesson took nearly one hour. We observed students were frequently off-task, either browsing 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 the video while completing the worksheet.

These two vignettes can be considered 'typical' during the laptop introduction in the sense that all lessons we observed were tailored to science topics and used a range of technology tools both on the laptop and peripheral in the classroom. Harriet encouraged students to explore the programs and she set up lessons where this type of activity was common. Mary used a more teacher-directed style generally, relying on the computers to access information. While some of the more specialized programs on the laptops may not be used every day, students were expected to take notes, look for and store information and compose homework and tasks on the computers. Thus in some ways, the laptops had replaced notebooks, textbooks or binders for the students. The laptops also collected a number of other very sophisticated technology tools into one place where they were, in theory at least, readily available. This is the potential represented with the laptops: a wider repertoire of tools for teachers and students to use to learn about science concepts, but also to collect and store all their learning digitally. Accessing and then utilizing the technology tools created particular challenges, which can be expected as an educational change is introduced. In the next section, we explore these challenges in terms of tensions and contradictions.

Tensions and Contradictions

The vignettes of the laptop lessons from our case teachers illustrated their general approach to lesson planning and technology use that we observed in other lessons. This section outlines and describes four key tensions and contradictions that emerged as themes from the data corpus of interviews and classroom observations. Analyzing tensions and contradictions helps to understand the teachers' response to this educational change through the choices they make (Kahveci et al. 2008).

Barriers to innovative science teaching

Innovative science teaching involves utilizing new technology tools in ways that create interesting and open-ended learning opportunities for science learners. Our two case teachers were leaders in this regard, as they planned lessons that used a wide range of technology tools on the laptops and peripheral equipment. In the first year of the laptop rollout, these teachers designed early lessons to help students acclimate to the changed learning environment including learning about the specific tools, procedures and capacities enabled with the laptops and loaded software. In her planning, Harriet specified the need to "build in quality teaching principles…and go beyond just using them; learning to make them more useful." Mary said her own planning with the laptops now involved attention to new classroom routines, demonstrating her own enthusiasm and challenging students in new ways: "I might give them a taste of a software package and then I'll give them a little project and I'll say, 'now you go off and put this together.'" And, "you're always learning in science, that's because there is always new information out there, new theories and resources coming out, on everything, like on human origins, always something, volcanic activity now that's happening worldwide." Contemporary issues were seeds for innovative science teaching according to Mary: "I've never taught the same thing twice and teaching is just not like that." The capabilities represented by the laptops offered new ways for these teachers to plan for student engagement with science.

As shown in the vignette, Harriet also planned lessons where students could explore the tools available on the computer. In another lesson we observed, she planned to have the students create unit review games using templates from a piece of software on the laptops. She scaffolded the students' activity through modelling how to use the software, and then instructed the students to make different one-page games with five questions each, where at least one game used multiple-choice questions. This was an innovative use of the technology to offer students choices, a degree of autonomy and the chance to be creative. Since other students were the audience for the questions and games, there was an authentic purpose for the students to create something useful for others as they reviewed material covered in the unit. The class period was devoted to this activity and at the end of the period the students were still actively working. Harriet instructed the students to finish this for homework and then email the files to her. Harriet subsequently reported the discovery that the files were too large for the school's email server. In reflecting on the lesson, she noted that the students were engaged with the task, but they struggled to ask good questions. Along with the large file size, this represented a barrier for Harriet's innovative use of the technology in her science classroom.

Our case teachers began planning for these sorts of engaging lessons even before the laptops arrived at their schools, attending workshops and professional learning sessions in anticipation. Both Harriet and Mary provided specific reasons why they organized their science lessons with activities using a range of technology tools: they wanted to utilize the rich potential offered by the tools; they wanted to actively engage students in higher order learning activities; and they saw the potential in such activities to foster critical engagement. These are 21st century skills but both teachers lamented that their students had commonly been very passive in working with science content information and thus were not as engaged as expected, even with the range of technology tools available and rich lesson activities. Our case teachers' lessons typically allowed students a range of choice for independent and self-directed learning about particular science concepts. This contrasts to a traditional 'stand and deliver' teaching mode, so common in secondary science and criticized as less-than-effective (Cuban 1986; Hewson & Hewson 1988).

At the beginning of the implementation period for the national one-to-one laptop program, our two case science teachers drew from their rich experience as science teachers to adapt to the technology. However, we suggest that there is a tension between these teachers' commitments to over-planning as an appropriate preparation for technology-intensive lessons and reliability issues for the equipment. In other words, when the technology failed, as it often did, even correct functioning did not engage the students in the ways imagined. It is, however, possible that the students lacked the skills to benefit from the rich planning the teachers had done.

These teachers' planning aims were entirely consistent with contemporary views of science education and educational policy that promote the conception of teacher as facilitator rather than knowledge transmitter (Park et al. 2010). Our case teachers' beliefs in lessons and activities for science students as engaging, multimedia, open-ended and rich were apparent from the vignettes and examples presented, however, these beliefs exist in tension with rhetoric and reality: good planning does not necessarily result in good learning.

Herein likes a key tension for science teachers: using the tools and technology enables layers to science lesson planning that allows teachers to range well beyond a traditional view of teacher as knowledge transmitter and model the kinds of 21st century learning behaviors and activities as noted by Wagner (2010). We observed these teacher behaviors including agility and adaptability with the technology and science content knowledge, but also being imaginative, curious and comfortable with uncertainty. From this, we see an uncommon flexibility in the case teachers' approaches to engaging their students and dealing with the barriers they regularly faced.

Classroom/school connectivity

Classroom and school connectivity lie at a critical intersection among the teachers' intentions, planning and goals for student learning using the laptops. Here, we consider connectivity as both student and teacher access to relevant hardware and software and internet or wireless networks in order to conduct the planned lesson. 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." Yet, planning assumes network availability.

At Northside High, Harriet could never be sure how many of her students would be able to access the wireless network in the science lab. We observed the students' experience of the network's on-going reliability issues: dead spots in the room and across the school grounds made them position themselves in sometimes-odd places for doing lesson activities. A further complication was that the upgraded wireless router for Harriet's science classroom could handle a maximum of 25 simultaneous users. When the 26th student attempted to log in, the system would lock up or crash. Rebooting the system and restarting all computers consumed 15-20 minutes of the 55-minute science block. Thus, Harriet regularly planned for an alternate, non-laptop version of her lessons, as she reflected during one of our early interviews with her.

At Southside High, where the laptop computers were delivered before functional internet access was available in many classrooms, including those in the science wing where Mary worked, installing a wireless network in this older, cement-block building required individual hubs for each classroom in the block. This became apparent only after the students were issued their laptops late in Term 2 of 2010, and connectivity problems revealed the inadequacy of the previous network.

From the vignette in Mary's classroom, her intentions to utilize the various technology tools in the classroom presented numerous challenges to implementing the day's lesson: Mary needed to be prepared for both classroom and student connectivity problems. Internet connectivity was but one of a variety of different connectivity problems, each of which had potential to derail the day's lesson. Mary later told us that in dealing with the multiple connection and log in issues, she simplified her lesson goal to ensure every student could connect to the Moodle.

Mary typically developed lessons using a variety of technology tools including special programs for which the school had purchased site licenses, as she reported in an interview prior to the lesson vignette. Having purchased

the licenses, school administrators wanted teachers to use the software. But, Clickview was not a program supplied on the laptops by the Department of Education (even as schools could opt to pay for site licensing), thus program use was not supported by the Department. This was a school-based decision that is the prerogative of local administrators. A consequence was that troubleshooting fell to the local level of the teacher. As a classroom teacher, Mary valued the option to use a program such as ClickView: "to watch a movie, it's really nice to be in a site, we could watch 10 minutes of this, because kids are so visual." Signing up with the private company was possible (which is the option Southside had chosen), but for whole group viewing, data projection is required. Site licensing may also place strictures on how individual students (or teachers) can access the videos in or out of school.

An additional connectivity issue involves students' out-of-school access to the internet. For example, when Harriet assigned assessment tasks, she had to ensure students had appropriate internet access or make accommodation for those who did not. At Northside, all of her Year 10 students had home internet access, but at Southside, only about 70% of Mary's students did. Of course, public internet access is available at local libraries or coffee shops, but the issue does mean that teachers must consider this when assigning out-of-school work requiring internet access. Internet access at home or in public places is essentially a social justice issue: children in areas that are economically disadvantaged may be differentially able to access information or bandwidth for homework or project work. Public libraries in such areas may suffer a similar challenge. The DER Strategic Plan (2008) assumes internet access at home: "Parents support students in their learning by monitoring programs and progress and by communicating with teachers online" (p. 4). While the universality of the laptop initiative mitigates differential access to the hardware (i.e. by providing laptop computers to everyone) or the wider possible differential with BYOD programs, the extended potential benefit of using a Department-supplied laptop outside of school is likely a function of the family economic position and/or the area in which the family resides.

While not specifically a connectivity problem, technical support underpins teachers' ability to utilize the laptops for teaching and learning activities. As noted in policy documents and reported by the teachers, each school has access to a Technical Support Officer who maintains the laptops, installs updates/upgrades and does general repairs. At Southside High, laptops were summoned by the technician (usually during class time) in bunches for software updates or servicing. This typically meant that, for two to three weeks at a time, and one to three times per year, the laptops were unavailable to the students in a particular class. Teachers were not generally notified of the call-in schedule and maintenance and upgrades often took longer than expected. At Northside High, Harriet reported

that individual student computers were on a schedule for maintenance and updating. This meant that at any given time six to eight students in a class were without their computers because the technician had them. When the computers were returned, it was possible that some students had different versions of software programs, both from other students and the teachers, whose personal computers may or may not be licensed for the student versions of the software.

Connectivity problems, whether due to the physical plan 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 to classroom management. Frequent connectivity issues and the flexibility needed to shift gears if/when hardware or software problems emerge mean planning for implementation needs to allow for this dynamism. Despite the teachers' intentions to create integrated experiential-based learning opportunities for their students, which Zucker and colleagues (Zucker and Hug 2008; Zucker and Light 2009) have noted can engage students in complex thinking, problem-solving, reflection and production, connectivity issues may in part be responsible for the generally low levels of motivation and cognitive engagement that our case teachers reported among their students, as described next.

Teacher vs. student expectations

In the lesson vignettes presented earlier, we saw examples of the teachers' personal commitments to developing technology-rich and engaging lessons to motivate their students. The teachers made regular and substantial investments in preparing and implementing these lessons for their Years 9 and 10 science classes, as evidenced by the multiple versions of the lesson plan and flexibility demonstrated in enacting them. Yet, Mary noted that: "this school is still pen and paper and whiteboards" and so, her students were in transition from a more traditional teaching and learning model. During one interview, she reflected:

> The kids are not sure what to write down. They'll wait, then copy anything that is written on the whiteboard. They copy it automatically, but with information on the computer, they are not sure, and ask 'Do we write this down?' or, 'What do we write down?' They're very much in that mode, teacher-oriented, focussed. (Mary, Interview, May 20, 2010)

We see this as a tension that may exist independently of the technology tools in use, but in the context of Mary's science classroom, we ask how or even if classroom practice necessarily changes with the introduction of new

educational technology. In other words, teachers need to work through the transition too. At Northside, the school's principal was guiding this transition, as noted by Harriet:

> He's pretty keen to make sure they are implemented. This year our professional learning centered around, 'Ok, you've got a computer in your classroom. Let's use it for something other than just looking at the internet. How can we build quality teaching principles?' (Harriet, Interview, April 15, 2010)

As part of the current research, and despite the teachers' efforts to integrate the computers into meaningful learning activity, we observed an overall reluctance by students to engage with the computers as a learning tool. According to Harriet,

> One of the things I'm worried about, I've noticed, kids are using their laptops to take notes, rather than in their books, but I'm not sure they've figured out the best way to take notes and if they're recording what they should, or whether they are recalling anything from it because there are different styles of learning. They still worry about learning to type, how to insert pictures….I'll be really interested to see their level of recall. (Interview, April 15, 2010)

At best, the students have more on-task time. At worst, they are bored, disengaged and resistant, sometimes belligerently so. In the lessons we observed, students were not self-directed or particularly engaged in the often elegant and highly interesting and demanding work that our case teachers designed into their laptop lessons. According to the case teachers, technology tools do not support higher levels of cognitive engagement even when the tasks are rich.

We suggest that there are several reasons for students' low levels of engagement. First, both teachers and students experienced immense frustration over ongoing connectivity issues. 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 tools may only place low cognitive demand on the students, which may suggest that teacher practice has not yet adapted to the available technology tools. However, we observed lessons that used a broad spectrum of technology tools. During the initial interview with Harriet, she described a unit of work she created for her upper-level Year 10 class:

> I put all the work on the wiki, and then the Department [of Education and Training] had it available, but then they locked it over the holidays for the kids. I was able to get it, so I projected it for the kids, but that meant they couldn't work through it independently.

The local issue of wiki access was never corrected by the Department. Instead, the Department abandoned its use, which meant Harriet abandoned this 100% on-line environment and returned to a more teacher-directed, less-independent delivery mode for that unit. The unit had also included a number of 'optional activities' that Harriet thought would be interesting and motivating for the students, but was surprised by their low-level engagement:

> They had to concentrate on the basics. One of them was 'Find a labelled diagram of the electromagnetic spectrum and cut and paste it into a document.' They could do that, but when I said, 'Find a labelled diagram of the ear and then create a table that gives the functions of the various parts,' I heard 'What sorts of functions?' 'How big should pictures be?' 'How many labels should we have?' and 'Is this one ok?'"

These are low-level questions that Harriet had not expected from the upper-level Year 10 students in this science class and may run counter to assumptions by policy makers, corporate executives and even practitioners that ubiquitous technology will lead to greater use in classrooms by teachers and learners (Cuban et al. 2001). It may be that the students' difficulties with task interpretation or working with text reflected their overall uncertainty and lack of confidence with the technology, manifest as a lack of self direction, even as Harriet felt the upper-level students to be capable of this work.

We agree with our case teachers that not every lesson can be highly engaging and utilize multiple resources, but using the internet for assignment work was pervasive. Commonly, students in lessons we observed dragged answers to their teacher-designed worksheets or to 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 on a day when Harriet had been called away for administrative duties. The worksheet 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. But, they had all filled in the worksheet in class two days previously. During a post-observation interview, Harriet reported that she has learned that students will often indiscriminately copy-and-paste answers from any internet site, and thus not meaningfully engage with 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 or to benefit from the potential offered by the range of possible activities with the available software programs.

Both teachers and students need to learn to use new software programs. The NSW Department of Education licensed a suite of programs for the laptop computers, most of which were new for both students and teachers. Frequently, the teachers scheduled class time for the students to 'have a go' with the program. Interested students spent time exploring the program; disinterested students moved off task, and others would be confused with the program and ask for help from the teacher, as we saw in the vignette from Mary's class. Teacher familiarity with the program was thus important, but the possible range of student behaviours meant teachers were faced with a 21st century classroom management issue: the need for both teachers and students to understand enough about 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.[3] 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 was consistent with 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 and Lucas 1997; Kubota and Olstad 1991) because high novelty may impede cognitive engagement. The initial high novelty of the laptops in schools may have impeded student use of 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 or in other jurisdictions contemplating similar programs.

Changes to classroom management

The ubiquitous presence of laptops creates new layers to classroom management. Computer-based lessons typically involve less teacher-directed activity with the teacher as facilitator. But, according to Mary, "making sure the kids are doing what they are supposed to do is one of the hardest things for teachers to check or manage" (Interview, May 20, 2010). This regulatory perspective exists in tension with the individual initiative assumed as part of 21st century learning (Wagner 2010). Both of our case teachers noted changes to their pre-laptop classroom management

[3] See postscript for a follow-up comment from Harriet on student engagement by these same students who completed Year 12 at the end of the 2012 school year.

strategies and realized implications for classroom pedagogy in implementing laptop use in the classroom. With more student-directed or independent work time, students can be off-task outside the teacher's awareness, since computer screens typically face the opposite direction to a teacher leading the class from the front of the room. 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.

Another aspect of classroom management involved submission of assignments. Students were often 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 appropriate server capacity and connectivity (at home, for example) are required. Thus, managing 21st century homework adds a layer to managing assessment. To resolve related issues, students saved and submitted their work on a USB thumb drive.

We noted 'regular' disruptions to classroom activity too. As follow-up to the vignette, Mary also moved her second class of students to another room to accommodate the digital technologies that had not operated as planned 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." Recent research around learning and digital technology is beginning to suggest that students dichotomize their technology use (Clark et al. 2009; Ito et al. 2010; Watkins 2009). Apparently, students perceive the use of highly interconnected technology, for example smartphones and iPads, as tools for social networking, and not for use as learning tools (Author 2013), although there appear to be some differences as students move to more advanced studies in physics (Moll et al. 2012). As student use of social media tools is better understood, classroom management must develop to accommodate a range of activities, likely some that include digital technologies and some that do not. And while "the laptops provided the teachers with the means to access and use computers in their daily teaching and to be flexible in their presentation of material to pupils" (Simpson and Payne 2004, p. 1), our case teachers faced the tension between this increased access and flexibility and the changed context for classroom management.

Discussion

In our case teachers' perspectives, the technology tools available on the laptop computers (along with associated digital technologies in the classroom) represented 21st century opportunity to learn science. The software tools for

data gathering, information processing/management and creating presentations created new opportunities for student engagement with a variety of science concepts. Seeking to enable their students to access the wealth of information on the internet and information processing tools available on the laptops provided opportunity for changes to the teachers' approaches to science lessons. The teachers worked to scaffold the students to search for information in a variety of ways and through a combination of teacher-directed and independent work, developed rich learning opportunities for their students.

Having noted tensions and contradictions in the two classrooms under study in this research, we turn to a discussion of implications for science teaching and future implementation. Our case teachers were early adopters of technology tools and were keenly interested in using laptops as learning tools to engage their students. Returning to our research question, our case teachers' perspectives on and responses to the one-to-one laptop program lead us to propose conditions of implementation whereby teacher responses can ultimately guide a wider shift to practices that support 21st century learning.

Teacher commitment, flexibility and persistence

Our two case teachers were committed to planning innovative science lessons and encouraging students to use the technology in creative ways, however, on some occasions they abandoned their lesson plans and spent the class troubleshooting connectivity and log-on issues. We suggest that this is why their commitment, flexibility and persistence were vital for on-going implementation. But, given the instability of some of the hardware and software (which may reflect on-going growing pains), teachers must also manage the challenge of unanticipated problems as part of their repertoires for classroom management. What if teachers are not as committed as these two case teachers? Efforts to ensure the smooth operation of the technology may foster their persistence. In other words, teachers will likely stay engaged longer in building their repertoire of laptop lessons if they do not have to constantly troubleshoot technical difficulties. This may involve developing in teachers the ability to plan for and manage a changed classroom environment as a form of teacher resiliency, which could be part of teacher professional learning in the process of implementing educational technology (see for example, Cuban et al. 2001; Lingard and Renshaw 2009; Warshauer 2006). Teachers (and students) could be further supported with backup or loaner computers,

particularly for when the individual computers are being updated or serviced. However, physical availability is but one aspect of being able to reliably use the laptops for learning activity.

Teacher knowledge and commitments

In addition to persistence, teachers need extensive background knowledge about technology use, tools available and pedagogical alternatives. This knowledge reflects our case teachers' commitments to the value of engaging learners through the technology. We observed that both case teachers generally developed a non-technology-based back-up lesson alongside the technology-rich version in the event of laptop or connectivity issues. We believe their ability to do this was a function of their rich experience as science teachers who had vast personal resources to draw from in lesson design and teaching methods, as noted by Harriet: "I guess I'm confident enough to deal with these technical glitches or you can always get the textbooks out of the back room." Notably, even for experienced and innovative science teachers, such as Harriet and Mary, the fall-back position was a traditional, teacher-directed style.

In the face of technological challenges, we were not surprised to see a return to a more traditional teacher-directed form of pedagogy, as seen in Mary's vignette. Indeed, Cuban et al. (2001) suggest that it is this entrenched history of traditional pedagogy that means technology does not cause teacher change as new forms of educational technology are introduced. In accord with Drayton et al. (2010), we suggest that our case teachers' commitments and persistence reflect their values in moving their students toward 21st century learning, which assumes a less teacher-centered pedagogy and even teacher learning as an aspect of classroom practice. Mary's earlier comment about how science teachers are always learning reflects her personal commitment to continue to develop her own classroom practice. Our case teachers' values and ability to be flexible seemed to manifest in how alternate plans were effected. And, both Harriet and Mary were keen early adopters of other technology tools (before the laptops) and highly experienced and knowledgeable science teachers, which we believe positioned them with relevant expertise to successfully negotiate challenges during the period of the laptop introduction.

Conclusion

In this study, we explored two case teachers' perceptions of and responses to the ubiquitous presence of laptop computers and associated digital technology during the rollout of Australia's Digital Education Revolution. The

Minister of Education and policy statements expressed hopefulness that teaching and learning would be transformed by this rollout. However, as we have seen, despite competent and experienced teachers who are able to create highly engaging and rich learning opportunities, students may not engage these opportunities in meaningful ways and so it will be important to develop ways and means of supporting teachers and students to utilize the technology as a learning tool.

This research was conducted during the introduction of the laptop program in two local high schools in 2010. As implementation continues, new challenges can be expected. During the third year of implementation, according to Newhouse (2008), computers can be expected to 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).

Reporting the current research has the benefit of 20/20 hindsight vision although our data was limited to the 2010 school year and the introductory period of the one-to-one laptop program. Problems with battery life and computer longevity emerged in the first year of implementation.[4] In order for the implementation to proceed over a longer time frame, a stronger community connection needs to be made and maintained. More particularly, technical capacity for servicing or recharging computers needs to be aligned with classroom schedules in order for teachers to plan more efficiently for their lessons, and around laptop availability. As Harriet noted, the fact that each student has a computer means the resources that have been used to supply and sustain computer labs can be directed elsewhere. This includes different uses for the physical space as well as technology and equipment in computer labs.

While this study did not examine students' technological proficiency, there is an underlying assumption of such. For example, at Northside, Harriet did some simple spreadsheet work with formulas, which students learn as part of computer skills classes in Years 7 and 8, but she noted "most of that has now been incorporated into the different faculties, for instance, science is supposed to do databases and spreadsheets. Maths is supposed to do rate sheets, drawing things." This 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 should be coordinated at the school and system levels, and when

[4] The Laptop User Agreement specifies that students are to bring the laptops to school fully charged each day and leave the charger at home (NSW DEC 2011). Even though the manufacturer's specifications suggested the laptop would operate all day on one charge, in actual practice, this has not been the case.

they are, the educational change that is the laptop computer introduction through the Digital Education Revolution will begin to push high school teachers and students toward 21st century learning.

The two highly capable case teachers in this study are early adopters of laptop computers in their science classes. They are probably not representative of the general teaching population, a fact that needs investigation to consider the wider impact of the DER on teachers' practice (See the program evaluation reports by Howard and Carcellor (2010) and Howard, Thurtell and Gigliotti (2012)). Both of our case teachers were open to exploring the possibilities represented 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 as capable classroom managers, were very persistent in working around technical issues. With their intentions for technology-rich science lessons, both Harriet and Mary used a variety of technology tools and software on the laptop computers, including open-source information, as well as common science lab equipment, and designed open-ended tasks that encouraged students to utilize the rich possibilities of the technology for science learning. However, as we have seen, innovating through lesson planning, organization and teacher resiliency are prerequisite rather than guarantee.

We also acknowledge that the research process can readily be seen as invasive to teachers' practice. Thus, allowing researchers to scrutinize classroom activity suggests that our teachers were less risk-averse than the teachers in Howard's (2011) research. While Howard was specifically considering teachers' perceptions of risk related to implementing educational technology, we suspect that the small number of teachers volunteering to participate in the current research reflects the risk-taking ability of those who have an uncommon level of confidence and competence. However, this also means that our case teachers' perspectives can help understand how to manage the learning environment when new technologies are introduced into science classrooms.

Given the enormous commitment by national and state governments in Australia to the Digital Education Revolution, it is important to consider teachers' perceptions and responses to the introduction of the laptop computers, as well as how they have been implemented by classroom teachers and how the laptop as a tool has impacted student learning (see Howard and Carcellor 2010; Howard et al. 2012). Commentary on how teachers have engaged the laptops as learning tools for students is an important question, since as this study shows, teachers are utilizing the technology and changing how they plan for and deliver instruction. These changes parallel Cuban et al.'s (2001) 'slow revolution explanation' and the inevitability of technological change as incremental and gradual, but the system is complex and fundamental change (on multiple levels) is difficult.

Some of these changes are a direct consequence of the DER laptop introduction but there are also unintended consequences of policy changes that force 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). And according to Zucker and Hug (2008), in a technology-rich environment, teachers need to be "masters of pedagogy" (p. 593).

The current research explored two science teachers' perceptions and responses to the introduction of laptop computers as a high level educational change. Developing understanding of the issues that teachers face in implementing laptop use requires a critical focus. Is the educational change represented by the laptop introduction in fact equipping our students to be 21st century learners as asserted by the Education Minister? Rhetoric at the national level in Australia suggests the path is straightforward:

> 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)

In the case of the DER NSW, classroom teachers are both political and functional means to the educational end of 21st century learning, and arguably there is more attention needed to effect the desired changes. The two case teachers' responses to the introduction of the one-to-one laptop program include significant changes to their pedagogical and managerial approaches to teaching. And while dealing with challenges in relation to contextual issues as well as students' access to the laptop computers, there are both direct and indirect consequences of the policy change represented by the Digital Education Revolution.

Postscript

The initial period of the DER laptop introduction is over and in follow-up informal conversations with our case teachers, further comments have been offered about student engagement. While still doing much hands-on work with the junior students (in terms of laptop use), Harriet, from Northside, reflected on her work with senior students:

> We have had a great deal of resistance from our senior students against the laptops - they have been leaving their laptops at home and it has become almost impossible for teachers with senior classes to rely on being able to use them in class. (personal communication, July 26, 2012)

The novelty has worn off and, further, the four-year DER program has ended. Many schools in 2012 did not issue laptops to individual students, rather, the computers are now class sets, and the one-to-one program has not been renewed for future years.

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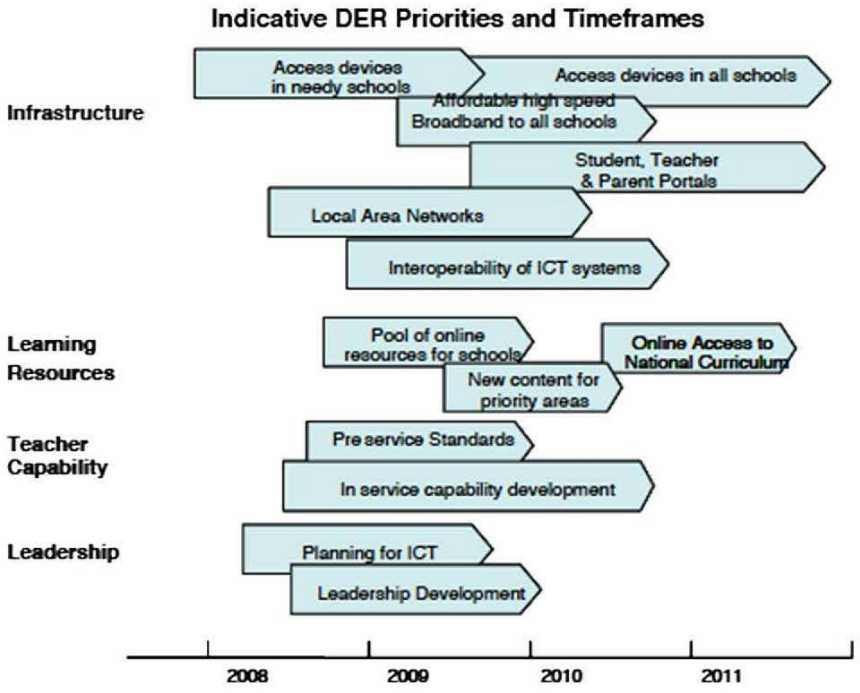

Fig. 1 Overview of DER implementation (DEEWR 2008, p. 10)