Integration of Laptop Computers in High School Biology: Teacher Perceptions

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Abstract

This paper presents a study on teacher perceptions of integrating laptop computers. The qualitative, descriptive study documents the role of high school biology teachers in the integration of laptop computers in the classroom, their perceptions of integrating laptops into their biology courses, key factors about the integration process, and how the integration was accomplished. The teachers who participated in the study identified ongoing challenges for accessing appropriate professional development, and for sharing knowledge, skills, and teaching materials.

Keywords

Laptops; Integration; Biology; Teachers; Instruction; Qualitative

Introduction

It was widely expected that computers would revolutionize teaching and learning (Dunleavy and Heinecke, 2008; Higgins and Spitunuk, 2008; Newhouse, 1999; Windschitl and Sahl, 2001). Research studies have consistently indicated that teachers, especially teachers in the senior high school grades and teachers of science, decided not to integrate computers, even laptop computers, into their instruction to the extent the researchers anticipated (Bain and Weston, 2009; Coffland and Strickland, 2004; Mara, 2006). Existing studies on the integration of laptops have tended not to focus on the role of the teachers, focusing instead on student attitudes, motivation, or possible increases in assessment scores on unit tests, or examinations (Chang and Tsai, 2005; Mouza, 2008). In addition, researchers noted that the use of computers for instruction did not diffuse easily within groups of teachers, although this research was not designed to ascertain why this is the case (Chamblee and Slough, 2002; Coffland and Strickland, 2004).

Laptop computers were first introduced into Australian schools in the late 1980s (Bain and Weston, 2009), but integrating laptop computers into instruction remains a more recent innovation in Canadian schools, and elsewhere around the world. While early research appeared to support the premise that the use of laptops may improve instruction by decreasing teacher-centred instruction and increasing student-centred learning (Dunleavy and Heinecke, 2008), the introduction of laptops does not automatically entail a change in modes of instruction. Some teachers in France and the United States, for example, were found to be using laptops as an add-on, with little change in their teacher-centred instructional practices (Amankwatia, 2008; Jaillet, 2004).

Despite a lack of studies focusing on teachers' perceptions, a number of researchers have concluded that whether desktop computers or laptop computers are integrated into instruction, and how they are integrated, depended on decisions made by individual classroom teachers (Feldman, 2004; Higgins and Spitunik, 2008). To determine the obstacles to integration and ways of overcoming the decisions of individual teachers not to integrate laptop computers (Clark, 2006; Donovan, Hartley and Strudler, 2007; Dunleavy and Heinecke, 2008; Tebbutt, 1999), there is a need to describe and interpret teachers' perceptions about the process they undertook, the problems they faced, and how they accomplished the integration. The study presented in this paper describes the perception of teachers concerning the integration of laptop technology in high school biology courses and how this innovation affects their instructional practices. Specifically, this paper focuses on how a purposeful sample of biology teachers described the integration of laptop computers into their courses, the supports they recognized, the challenges they identified during the process of integration, and the probable diffusion of this innovation to colleagues. The next section will examine factors which have been found to affect the integration of laptop computers into instruction and then, factors which have been

found to affect the integration of laptop computers into senior high school science classrooms.

Integrating Laptops in Science Education

Bell and Bell (2005) and Newhouse and Rennie (2001) identified factors that influenced the use of laptops for instruction such as positive expectations of school administrators and parents that the laptops would be used for instruction, not just for school management and communication. Factors that hinder the use of laptops for instruction include: the perception that others (colleagues, parents, students) might not support a change in teaching approaches; a concentration on external standardized testing that diverts resources from other projects; a lack of time to manage innovation; and, the lack of expert assistance. For instance, the allocation of support staff in schools is often not considered for science teachers, or for students learning in science laboratories, but is typically focused on special education students (Levin and Fullan, 2009). Early research in the field found that teachers who initially maintained a neutral response about integrating laptops became increasingly negative (Newhouse, 2001), based on their perceptions of existing attitudes, beliefs, preferred instructional practices, early obstacles they experienced in integrating laptops, and obstacles experienced by other teachers (Parr, 1999). Other factors that impeded the integration of instruction with laptops included a perceived lack of time and encouragement. All in all, few teachers integrated substantial computer use, and many teachers who did perceived a very limited role for the laptops.

Tebbutt (1999), and Lowther, Ross, and Morrison (2003) observed that poorly understood factors, such as the amount of time, effort, and organization required of the teachers to use the laptops effectively were pivotal factors, and that by itself, the technical ability to use laptop technology was not sufficient to insure that teachers would integrate the laptops into instruction. Few differences in teaching methods between laptop classrooms and control classrooms were reported and there was a lack of empirical evidence to document the difference laptops make to instruction (Albion, 1999; Smith, Dilts, Gabrielson, Heruth, Rettig, and Strautman, 1999). However, the burden on teachers seeking to integrate laptop computers into their teaching was noted. Higgins and Spitulik (2008) described what they call a double innovation which includes: first of all, learning about the technology, peripherals, the software appropriate for their students, and the management of computers in the classroom; and secondly, integrating an appropriate curriculum for the technology, which means dealing with content, teacher roles, assessment, and student achievement. While acknowledging the importance of the teachers in this double innovation process, none of the studies dealt with the decisions teachers make about adapting and integrating laptop computers into their curriculum or about how they accomplish or seek to accomplish this integration (Dunleavy and Heinecke, 2008; Higgins and Spitulik, 2008). If pedagogy and theory are to be developed in this area (Higgins and Spitulik, 2008), there is a pressing need for description of the decisions teachers make as they work to integrate laptop computers into their instructional practices (Mara, 2006; Varma, Husic, and Linn, 2008).

Certainly, early researchers, including Siegle and Foster (2001), noted evidence of a pattern of underuse of the laptop computers, in senior high school grades and in science courses in those grades. They observed that teachers need more subject-specific knowledge and assistance on how to teach science with laptop computers (Dunleavy and Heinecke, 2008; Higgins and Spitulik, 2008; Klopfer, Yoon, and Perry, 2005). As was stated earlier, research has largely avoided a focus on teacher concerns about integrating laptops into instruction, what influenced them to try, or how they sought to accomplish this integration. Invariably, there is little to indicate that the researchers asked the teachers about their concerns about integrating laptops into their instruction. The research on integrating laptops into instruction in science has continued to by-pass the role of the teacher and has continued to cluster around student achievement, attitudes and class environment (Chang and Tsai, 2005; Klopfer, Yoon, and Perry, 2005; Mouza, 2008; Owusu, Monney, Appiah, and Wilmot, 2010; Webb, 2005). There are a number of studies that speak to the issue of teaching science with laptop computers, but the specific grades in high school in these studies are not identified (Phillips, Bailey, Fisher, and Harrison, 1999; Tebbutt, 1999; Varma, Husic, and Linn, 2008).

Science teachers reported that software they intended to use had often gone missing, that software was unexpectedly not available, or that software was more difficult to use than expected (Becker and Ravitz, 1999) and, that the hardware and software provided at the school was unreliable (Reid, 2002). Such unreliability of hardware and access to software makes classroom

teaching very time-consuming and adds a stress factor that can impede integration.

Furthermore, science teachers expressed the need for equality of access to hardware and software for all students, both in class and outside of the classroom (Becker, 1994). They also expressed a need for sufficient hardware, one computer for every four students, and software sufficient to support whole-class activities (Becker and Ravitz, 1999) and, they reported having to deal with a limited range of software (Becker, 1994; Becker and Ravitz, 1999). Given these concerns, science teachers said the conditions in which they had to use desktops in schools, typically fell below the critical level of knowledge, support, and availability that would have encouraged them to integrate computers in their courses.

Researchers have observed that teachers with strong subject matter knowledge tend to employ, or at least consider, more effective or innovative teaching strategies (Becker, 1994; Davis, Petish, and Smithey, 2006) and confirmed that biology teachers bring creativity and commitment to the integration of innovations in their classrooms (Simmie, 2007). However, an enactment orientation to implementation requires multiple simultaneous change for an innovation to be successfully integrated, and it is the individual teachers who determine what innovations will be integrated and how such innovations will be integrated in the classroom (Becker, 2000, Chamblee and Slough, 2002; Feldman, 2004; Higgins and Spitunik, 2008; Windschitl and Sahl, 2002). Given the nature of science curricula, science teachers may have more experience implementing curricula with fidelity and adaptation orientations than implementing curricula with an enactment orientation (Hodson, 2001; Leithwood, Janzi and Steinbach, 1999; White and Tischer, 1986). There remains a need, therefore for studies focused on teachers as they strive to integrate laptop computers, and on the diffusion of instructional practices using laptops in biology courses at the senior high school level.

Researchers anticipated that laptop programs would have addressed many of the concerns science teachers cited as discouraging them from integrating previous forms of computer technology, including: lack of equality of pupil access to computers; one computer for every four students; lack of software for whole class instruction; a limited range of software; and software that had gone missing in the school (Becker, 1994; Becker and Ravitz, 1999). Researchers also anticipated that the introduction of laptops and computers would encourage teachers to alter their teaching practices, leading to less teacher-centred instruction and more student-centred instruction (Amankwatia, 2008; Mayer-Smith, Pedretti, and Woodrow, 1998). Nevertheless, under-utilisation of laptop technology and little change in science instruction continue to characterize teaching and learning in the senior grades of high school (Cuban, 1995). Gregoire Gill (2006) has raised the difficulties inherent in ascertaining teachers' perceptions about teaching and learning despite the importance of these perceptions on curriculum and pedagogical decisions affecting classrooms. These difficulties are an important consideration since existing research (Becker, 2000, Chamblee and Slough, 2002; Feldman, 2004; Higgins and Spitunik, 2008; Windschitl and Sahl, 2002) indicates classroom teachers largely determine if and how laptops will be integrated into instruction. Such an examination of their perceptions would allow a better understanding of the challenges of integrating laptop computers in science and a descriptive study design was selected to fulfill this purpose.

Design of the Study

Qualitative research can be used to collect data on 'how' and 'what' questions as described above, and where the researcher has no control over the actual event being studied (Yin, 1994). Stake observed that qualitative research can also be used to study phenomena that take a long time to happen, phenomena which evolve along the way, and where it often takes a long time to understand what it going on (Stake, 1995). Within qualitative research there are many strategies for inquiry, from biography to grounded theory. Inductive analysis of the data obtained involves discovering patterns, categories and themes in the data. The study described in this paper was designed to describe biology teachers' perceptions and experiences as they integrated laptops into their instruction. It was not designed to test hypotheses or develop theory (Seidman, 2006).

Descriptive Study

Descriptive studies have greatly increased knowledge of what goes on in schools (Gall, Borg, and Gall, 1996) since they explore actions, events, frames of reference, and processes in natural settings such as classrooms. A descriptive study was appropriate for this research designed as it was to describe teachers' perceptions

concerning the implementation of laptop technology in high school biology courses and to provide the opportunity for teachers in the sample to reflect on their experiences. This descriptive study stresses the importance of the context in which biology teachers teach, their perceptions, and seeks to hear their voices and understand their lived experiences as they integrate laptop computers into their high school biology programs (Marshall and Rossman, 2006).

The design of the study relies on previous research, largely quantitative in nature, which identified science teachers as a special population within schools, slow to integrate laptop computers into instruction especially in the senior grades, and which recommended further qualitative research to explore teachers' perspectives of what was happening in their classrooms (Becker, 1994; Hakverdi, 2005). As Bain and Weston (2009) observed, this problem was analyzed a decade ago. This study also relies on previous research, largely qualitative in nature, which identified that teachers need information about integrating laptops into instruction and a better understanding of the processes if they are to succeed, and that a decade after the problem was analyzed, these needs are not being met (Dunleavy, Dextert, and Heinecke, 2007; Tebbutt, 1999).

To determine the obstacles to integration and ways of overcoming the reluctance to integrate, there is a need to describe and interpret teachers' perceptions about the process they undertook, the problems they faced, and how they accomplished the integration. Perceptions are defined in this study as teachers' intuitive insights based on their experiences in classrooms, schools, and their years of studying and teaching science. The study presented in this paper has two objectives: it proposes to examine perceptions of the teachers included in the study sample concerning the integration of laptop technology in high school biology courses and how this integration affected their instructional practices

In order to fulfill these objectives this descriptive study is based on the following research questions:

Question One: How do senior grade biology teachers perceive the integration of laptop computers into high school biology programs?

Question Two: How do senior grade biology teachers perceive and introduce new teaching approaches when integrating laptop computers into high school biology programs?

Question Three: What new teaching materials do senior grade biology teachers use when integrating laptop computers into high school biology programs?

The descriptive approach to answering these questions ensured that the research was conducted in a manner that captured the perceptions and experiences of the teachers. Multiple sources of information were sought: three semi-structured interviews; informal interviews; follow-up question; and, the collection of new teaching materials the teachers had prepared.

The Participants

A purposeful sample (Cresswell, 1998: Merriam, 1988) was sought of ten teachers who were teaching biology in the final two years of high school, in laptop environments where teachers and students have access to personal laptops and the same software. Sites, first public schools and then private schools, were sought in Ontario, Canada, where laptops were being used with a range of software including probes and data bases, with a view to enhancing the learning of science, rather than simply as word processing and presentation tools (Stolarchuk and Fisher, 2001). The schools where teachers were granted permission to participate in the study were private schools and the teachers volunteered to participate.

The ten teachers who volunteered to participate in the study had strong backgrounds in science and biology and were academically qualified to teach high school biology courses. All had undergraduate degrees in science from Ontario universities. In addition to their original undergraduate degrees, they reported having completed additional undergraduate credits in chemistry, physics, radiation biophysics, neural anatomy, and psychology. Five had graduate degrees: four had a M.Sc. or M.A. in science, one had an M. Ed., and two of these teachers had started, or had been about to start, a Ph.D. program in science when they decided to return to teaching high school science.

At the time of the study, all were teaching in Ontario in schools which followed the Ontario Curriculum. All of the teachers taught Biology 11 and/or Biology 12. Five of the ten teachers had students writing biology exams for external programs (International Baccalaureate or Advanced Placement) to which their schools had subscribed. All of the teachers encouraged the students to participate in biology competitions. These teachers were teaching four to five classes at the time of the study and almost without exception, these were science courses ranging from

grades eight to twelve. The number of different preparations per teacher varied from one to six, with the average number of preparations being four science courses.

The teachers came to a laptop program from a variety of backgrounds ranging from having chosen not to teach with the desktop computers available in their classrooms or in computer labs at their schools, to having taught with sophisticated networked desktop systems whose main difference from a laptop program was that the students did not necessarily have easy access to a personal computer. Other teachers in the study had begun their teaching careers in the laptop program now in use at their schools.

Data Collection

Having chosen to conduct a descriptive study, appropriate strategies for collecting data were selected (Seidman, 2006). Three semi-structured one hour interviews were conducted with each teacher. The first interview was used to review teacher background, to gather teachers' perceptions and information on changes in teaching approaches, and the use of new instructional materials. The second interview was used to gather the teachers' perceptions about integrating laptops into instruction and new teaching material prepared by the teachers was requested. The third interview was used to explore the teachers' perceptions of their future plans to integrate laptops into their teaching, their opinion of the possibility that other biology teachers would integrate laptops into instruction, and samples of new teaching materials were collected. Follow-up questions and additional informal interviews were used to investigate any remaining issues.

Data Analysis

An intense analysis of the data followed the data collection (Merriam, 1988). Data are typically collected, organized, and then reorganized in a form that may vary from the original description. This process is described as "uncovering and discovering themes that run through the raw data, and interpreting the implication of those themes" (O'Leary, 2009, p. 204).

The recordings of the interviews were converted to a computerized transcript and the data collected were first analyzed by hand. Although there was no prior intent to develop theory from this descriptive study, the initial themes and categories developed were entered into the software NVivo and the text was coded. The NVivo software has the capability to structure and organize data (Willis and Jost, 1999), and makes it easier to rework data analyses as additional data are collected, and to integrate new themes as they emerge (Richards and Richards, 1994; Willis and Jost, 1999).

Themes for analysis were generated from the research questions and the literature review (Merriam, 1988), and these initial themes were re-evaluated as the data were analyzed. In this study, topics raised with the teachers during interviews resulted in themes based on their experiences. The participants were also given the opportunity to review the information they provided for accuracy and so they could provide additional information.

Within the structure of a descriptive study, the teachers provide perceptions based on their practices in their classrooms and schools. The next section examines their perceptions, and allows a better understanding of the challenges of integrating laptop computers in science instruction.

Results

The teachers' perceptions as they integrated the laptop computers into their instruction dealt with four themes: how the integration was accomplished; what the teachers perceived supported their ability to modify their instruction; what challenges the teachers perceived they faced, and still face, in changing their instruction; and, how they perceive the integration of laptop computers diffuses to other biology teachers. In this section of the paper, their perceptions are dealt with in that order.

How the Integration was Accomplished

Teachers in the study indicated that they decided how the laptops would be used in their classrooms and that they recognized that how they chose to integrate the laptop computers was possibly unique among their colleagues. While the teachers reported some collaboration with colleagues on academic matters or content, they made individual decisions as to what the laptops were used for and how the laptops were used in their classrooms. Only three teachers described having shared lesson plans or planning with teaching partners. In addition, four teachers noted that the Information Technology (IT) department assisted with software the teachers wished to use for teaching in biology. All the teachers described a gradual or evolutionary pattern of integrating laptop computers

into their instruction. As one teacher observed, changes in instructional approaches resulting from the use of laptops happened over time

> Over a period of time. I think it
> was a big adjustment for the
> students as well as the teachers
> so it didn't happen quickly
> (Adele, I - 247).

The decision-making pattern for pedagogical matters described above was very different from the process the teachers described for the integration of hardware and software to be used throughout the school by teachers in all subjects. In this latter instance, where the laptops were used for administrative or non-pedagogical purposes, the teachers did not make the decisions as to what would be integrated or when an innovation would be integrated. Nonetheless, a few had some input into the decision making process, including: collaboration with the IT department; participation in pilot projects; the provision of a teacher who had some release time to work with teachers on the integration of the generic aspects of using the laptops; and, occasionally, collaboration with the vice-principal.

By contrast, when talking of the challenges in finding appropriate professional development and appropriate models for instruction, a sense of isolation is communicated.

> It's important for groups
> of individuals that are perhaps
> using this (laptops) in some
> fashion to get together, and
> share best practices and to
> discuss things that might be
> possible. If we could do that,
> we might be able to take away
> something that would help us.
> (Keith, III – 73).

Teachers reported that it had taken two or three years to integrate laptops into their instruction; however, they acknowledged that the innovations would be ongoing for a number of reasons, including: they might be teaching different courses; changes in the province's curriculum guidelines; changes in teaching partners; new software programs they wanted to introduce; and, innovations they would introduce to reflect student needs. These teachers envisioned the endpoint of the integration process as every lesson having some integration of the laptops. Eight teachers reported that they had reached the point in the integration process where they were now substituting better labs and better data gathering experiences for the students.

Supports during Integration

When asked what had supported their efforts through the challenges associated with integrating laptop computers into their instruction, a number of themes emerged including: the students, the schools, professional development, instruction and, themselves as teachers. These factors are dealt with in more detail in this section.

Teachers cited positive, if anecdotal, feedback from students and alumnae/i that encouraged them in their efforts to integrate laptops into their instruction. Students described feeling better prepared for post-secondary studies; and, alumnae/i reported feeling better prepared to succeed at the post-secondary level through participation in the laptop program.

Teachers stressed the importance of the role played by the school, sometimes identified as "the administration" or "the IT department", in supporting the integration of the laptop computers in their classrooms. For most of these teachers, evidence of this support is the provision of the peripherals needed to teach biology with laptop computers, and the provision of up-to-date technology. Teachers also stressed the importance of the professional development provided by the IT department. Having professional development at the school was seen as a great advantage, preferably at times scheduled into their timetables, and preferably to address the needs they as teachers identified.

> How can this be done now?
> PD? I would say through teachers
> sharing how to integrate laptops
> into teaching. It has to be sharing
> sessions and my idea, which I'd
> love to see happen in the future,
> would be to actually host

a technology conference of some
sort where teachers share
(Darby, II - 39).

These teachers described being encouraged by the fact that the school had designated funds available for them to attend conferences, workshops, and/or courses, as well as noting the importance of financial support available through the IT department's budget.

I'd emphasize the necessity
of having a lot of financial
support because IT in
biology, certainly when I think
of the money I spent just recently
on probes, is sometimes an
entire science department budget
at certain schools
(Xandra, III - 129).

The teachers also noted the importance of the financial support they had received from the school in the initial stages of integrating the laptop program, including: loans and subsidies to purchase personal laptop computers, and the additional professional development opportunities provided for them at that time. Some teachers observed that it just wouldn't be worth the effort of integrating laptop computers into instruction if they were working with out-of-date technology. Others commented that once a school is in a laptop program there is no going back, since all the schools most comparable to the school where they were teaching had introduced laptop programs.

Teachers observed that innovations they had already made in instructional approaches encouraged them to continue the process of integrating laptops into their biology programs, although the reasons they provided were variable. Many described learning from the students as they integrated the laptops into their instruction and being stimulated by the students' interest in the biology course, as well as by the increase they perceived in student learning and motivation. One teacher said she was encouraged to continue the integration in her classroom because she could select her own peripherals and she could decide how the technology was to be used in her classroom.

Different types of software
were brought to my attention.
I don't use them all regularly,
I have my repertoire of what
I am comfortable using
(Xandra I – 76).

Personal characteristics, perhaps unique to them as individual teachers, encouraged them to continue the process of integrating laptop computers into their instruction, including: a positive attitude to integrating innovations; the ability to deal with the time constraints of teaching a laboratory subject; and, their increasing proficiency within the laptop program which motivated them to continue the process. Teachers reported that they were encouraged by new ideas they could adapt for their courses and by seeing what other teachers in laptop programs were doing in other schools. Others found they were encouraged to continue the integration of laptop computers because they became more efficient with regard to preparing lessons and classroom teaching.

Still other teachers identified improvements in the instruction of their biology courses, including: more learning experiences for the students; the increase in students' output in the laptop program; students liked the coursework more; and, students were less stressed by the requirements of the course. These teachers noted the importance they placed on having the software they required to teach biology, and the importance of acquiring new software and hardware which they anticipated would make the process of incorporating different kinds of teaching materials into their instruction more efficient. These teachers outlined a number of professional development activities which they considered to be important, including: hearing about integrating laptops into instruction from colleagues during staff meetings; the support provided when technology "experts" were invited to the school to demonstrate new equipment to the teachers (and in one school, to the students as well); and, having colleagues present during professional development opportunities. This was seen as an advantage for follow-up after the professional development experience and for mentoring within the science department. Some of these teachers said they were encouraged to continue integrating laptop computers into their instruction by standards for technology use in biology courses issued by the Ontario Ministry of Education and the International Baccalaureate, by program evaluations carried out at

their school, and by the feedback they received from such program evaluations.

When asked what had supported their efforts through the challenges associated with integrating laptop computers into their instruction, a number of factors emerged including: the students, the schools, professional development, instruction and, themselves as teachers. The challenges they identified are dealt with in more detail in the following section.

Challenges to Integration

When asked about the integration of laptops in their instruction, the teachers identified a number of challenges, including: the ongoing nature of technological innovations; instructional issues, such as their personal lack of knowledge and skills, varying the delivery of lessons, and individualizing instruction in the laptop program; their extra-curricular role as a teacher in the school; finding appropriate professional development; and, issues associated with the maturity of students in high school laptop programs.

Challenges the teachers in the study associated with technological innovation included issues with hardware, software, and the peripherals used with the laptops to teach biology. Surprisingly however, many of the observations about hardware are positive in nature, including: upgrades such as laptops with tablet and stylus capability will make it easier to collect, mark and return student work; and, more network speed, capacity, and wireless capability, will make it easier to use the laptops for instruction during the school day. The unintended, sometimes negative, consequences of hardware updates, which result from the acquisition of new laptops, are noted with philosophical resignation as the price of progress. Similarly, it is thought that improvements in software and upgrades in peripherals, such as probeware and SMART Boards which can be controlled by touch, will enhance teaching in the laptop program in the future. Dealing with the inevitable incompatibility between existing resources and newly acquired resources, although challenging, was again viewed as the price of progress.

Generally, teachers did not express concerns about instruction, but some did describe instructional challenges. Their concerns included: varying the delivery of classes in a laptop program; varying their teaching approaches; individualizing instruction for different classes and different students; the time and energy required to double-check teaching resources each year before they can be used in the classroom; the tedious and cumbersome process for receiving, marking, and returning student work; and, the fact that the different nature of the Biology 11 and Biology 12 courses presented different instructional challenges for them.

Teachers raised concerns regarding their personal level of knowledge and what they still need to learn if they are to teach more effectively in a laptop program. They commented that teaching with laptops in a laboratory subject made it more difficult to schedule the blocks of time they needed to master and integrate hardware, software and peripherals into their instruction, than if they had been teaching another subject in the school. Most of the biology teachers either had no assistance in the laboratory or they had technical support that changed frequently (such as university co-op students on work terms), which consistently, year after year, requires more input of additional time and energy from the teachers.

Similarly, teachers considered accessing appropriate professional development as a challenge. Most teachers articulated a need for more training on the technology they used to teach biology, and a wish to find appropriate teaching models to observe and opportunities to share with other teachers in other laptop biology programs. The need to provide students with more effective learning opportunities is recognized by teachers, as are the associated challenges of providing a laptop program to teenagers. The teachers acknowledge that learning experiences needed to be tailored to a realistic level of maturity for adolescent students. One teacher, identifying the need for feedback on his teaching approaches in the laptop program, noted that he is of the opinion that no one even has the tools to provide that type of feedback to teachers like him.

When asked about the integration of laptops in their instruction, the teachers identified a number of challenges. Their responses reflected their personal experience, but the teachers were also asked for their perceptions on how other biology teachers would meet these challenges. The next section deals with the probable integration of laptop computers into other biology teachers' instruction.

Perception of Diffusion of Integration

In terms of their perception on the integration of laptop computers, some teachers said they can no longer imagine teaching without a laptop and that as a

result of their involvement in the laptop program they might be different from other biology teachers in a number of ways, including: more forward thinking, in the sense of innovative (Becker, 1994; Davis, 2006) or creative and committed (Simmie, 2007); more willing to modify their practices; more current; more effective; more enthusiastic; more willing to learn from their students; and, more willing to consult the literature while teaching. They believed their biology courses might also be different in a number of ways: the courses had become more entertaining for the students; instruction and teaching approaches had become more varied: and, the learning styles of a wider variety of students were being met. They believed that their courses and lessons in the laptop program were more interesting for the students and easier for them to prepare. The teachers cited: the lack of photocopying; less writing on the chalkboard; the use of power point presentations, websites, and simulations from the internet during lessons; less teaching from the textbook; and, the use of email for communication within the school community.

These teachers advised that new colleagues should plan to integrate the laptops only to their personal comfort level and they should continue to use the teaching approaches, techniques and teaching materials that worked for them in the past as they begin the process of integrating laptops into their instruction. They recommended alternating traditional laboratory experiments the teachers would have used in other schools with laboratory experiences they have redesigned for use with laptops and the teachers in this sample see opportunities for introducing more student-centred activities and decreasing the time spent on teacher-centred activities.

Still others note it is important that new colleagues accept that the process of integrating laptop computers is an ongoing challenge. The teachers in the sample provided advice on how to start reorganizing courses and lessons and how to start using the laptops, including: check the curriculum to find concrete ways to show students what technology can contribute to the learning of biology; realize that laptop use will vary with the content of the biology course being taught; use a variety of teaching approaches in the classroom; realize the laptops do not have to be used every day; and, start the conversion to teaching with laptops with their favourite topics and the key labs in the course. These teachers also advise that since the maturity level of the students will influence what can be done with the laptops, it might be wise to start with courses for grade twelve students rather than grade nine or grade ten students.

When asked what would encourage biology teachers to integrate laptops into their instruction, teachers said that the realization that students were learning better and more successfully will encourage new colleagues. The teachers in the sample also recognized that new teachers are encouraged if the school identifies the laptop program as a priority and has high expectations for the teachers and students in the program. The teachers explained that new colleagues will also be encouraged as they begin to understand that integrating laptops into their instruction is an innovation that works in the classroom and, despite any flaws, has enormous potential for future teaching. Teachers believed that a number of factors would encourage new colleagues, including: their teaching will become more effective and efficient as they adjust to their role as a facilitator in the classroom; they will realize they can become happier, more fulfilled teachers in a laptop program; that with laptops it is easier to supplement student learning; and, that time spent on integrating the laptops in one year saves time in future years. These teachers also believed that new colleagues would be encouraged by the growing realization that it would be hard to go back to teaching their biology courses without laptops.

Discussion

The teachers who volunteered for this study have a combination of undergraduate degrees in science, graduate degrees, professional certificates, specialist certificates, experience teaching science at the intermediate level, experience teaching science at the post-secondary level, and years of experience teaching grade 11 and 12 biology courses. While not all the teachers in the sample possess each of these characteristics, the combination of the characteristics that they do possess as biology teachers is noteworthy. Based on Becker's earlier study (1994), and a study by Davis (2006) which confirms that secondary science teachers with strong subject-matter knowledge tend to employ, or at least consider, more effective or innovative teaching strategies, there is a high likelihood that the teachers in this study's sample would be willing to integrate laptop computers into their instruction and be willing to sustain the innovation after the initial implementation.

There was little in the research literature reviewed for this study to validate the data the high school teachers

in the sample provided on integrating laptops into their instruction. In fact, Russell (2006) reported that most research about the secondary level is carried out by the tertiary level rather than by the secondary level and, Inan, Lowther, Ross, and Strahl, (2010) observe that teaching approaches and materials differ with grade level and subject area. Certainly, most of the research located for this study tended to have been carried out at other educational levels or in other subjects, including: the post-secondary level (Bell and Bell, 2005; Ferdig, 2006; Landry and Hartman, 2006; Reading, Fluck, Trinidad, Smith, Shaw, Anderson, McLoughlin, and White, 2006; van Oostven and Muirhead, 2007; Windschitl and Sahl, 2002); in middle school science (Kiboss, Ndirangu, and Wikesa, 2004; Moore, 2004; Rogan, 2007); or in subjects other than science (Kearny and Schuck, 2007).

The teachers' perceptions on the integration of laptop computers into their instruction were remarkably consistent. They considered the integration of laptop computers into instruction to be a teacher initiated innovation in that they decided which changes were integrated into instruction in their respective classrooms and they decided how the changes they integrated into instruction varied from class to class. They described managing an evolutionary pattern of change in the classroom and they expected they would be dealing with new and continuing adaptations affecting their instruction in years to come.

For the majority of the teachers, the changes to their instruction had been profound. For these teachers, laptops were used initially as add-ons to the program they had been teaching, or had been trained to teach, but the original role of the laptops was systematically expanded to affect almost all aspects of their teaching, with the possible exception of assessment procedures and marking student work. The teachers had introduced different teaching approaches, including; how lessons were prepared and delivered in the classroom; increasing the number and improving the nature of the labs the students completed; the inclusion of active learning experiences including more pertinent and interesting homework assignments; and more communication with the students outside of the classroom. As a result of the new teaching approaches they introduced, the teachers listed a number of ways the courses they were now teaching were better, including terms such as: more relevant; more up to date; more interesting to the students; more student-centred than before; and, providing a better preparation for studying biology at the post-secondary level. While they believed that their new approaches to teaching in the laptop program had increased communications between students, between teachers and students, and between parents and teachers, there was still very little evidence of increased electronic communication beyond the walls of the school, between students in different schools, between teachers in different schools, or with experts in appropriate scientific fields.

While implementing a laptop computer program is a school-based decision, Information Technology (IT) departments typically may not provide backup to the teachers specific to the pedagogical use of laptops as recommended by Inan, Lowther, Ross and Strahl (2010). Rogan (2007) commented on the lack of understanding in schools and school systems regarding the enormity of the changes required of science teachers when they implement an innovation such as the integration of laptop computers, and the lack of detail provided by schools and school systems on how teachers might implement such large-scale innovations. Moore (2004) confirmed the complexity of the implementation processes that teachers are exposed to in schools when implementing multiple, simultaneous innovations such as the integration of laptop computers into instruction. A great deal of the information the teachers in the sample provided during the interviews dealt with the time and effort spent in IT professional development in order to learn the technology used to manage the school's administrative functions as opposed to implementing laptops in the classroom.

Teachers felt supported through the process of integrating laptops into instruction by the following: feedback from the students they taught and have taught; the professional development made available to them; the school's support, whether through the administrators or through the IT department; the improvement they perceived in their teaching performance; and, the improvement they perceived in themselves as professionals. But, the teachers participating in this study identified a number of on-going challenges that they continue to face as they develop their use of laptops for instructional purposes including: finding professional development appropriate for senior grade biology teachers in a laptop program; having the opportunity to observe other teachers teach biology in a laptop program; accessing ideas for new teaching approaches; and, finding, locating and obtaining new teaching materials they can use in their respective classrooms. These

challenges are exacerbated by the relative isolation within which even teachers who share similar courses, and learning and teaching objectives typically were functioning. There was, for example, little evidence that the teachers from different schools who volunteered for this study knew one another, even though they shared similar pedagogical challenges and aspirations, their schools were all within a 500-kilometre radius of one another, and their schools participated in common sports competitions, drama and music festivals. In addition, the teachers identified the ability to deal with challenges, and the willingness to change teaching approaches and prepare new teaching materials, as important characteristics if new colleagues were to be successful in a laptop program. Support by the school and scheduled at the school, was deemed important as new teachers entered the laptop program. They observed new teachers would be encouraged by the more effective instructional practices available in a laptop program, but only if they could cope with the ongoing nature of implementing innovations in a laptop program.

Conclusions

The research reported in this paper is among the first to study change in practice when integrating laptops into instruction in senior biology courses. As discussed, studies have consistently indicated that teachers, especially teachers in the senior high school grades, and teachers of science, have not integrated computers, not even laptop computers, into their instructional practices to the extent anticipated by researchers. Existing studies on the pedagogical integration of laptops have not focused on the role of the teacher, focusing instead on student attitudes and on measuring possible gains in student achievement. Research studies also have indicated that the use of computers for instruction does not diffuse easily from teacher to teacher although, not having been designed to ascertain why this was so, they cannot speak to the dynamics that militate against diffusion. Through concentrating on the perceptions of teachers who are either charged with, or who self-initiate, the pedagogical integration of laptop computing in their respective senior science classrooms, our study contributes to the practical knowledge requisite to integrating this initiative in the classroom and the diffusing of its potential success among teachers, schools and school systems.

Much of the previously existing research (Cho, 1998; Klopfer, Yoon and Perry, 2005; Kumar and Crippen, 2005; Rutherford, 2005; White and Tischer, 1986) focusing on the integration of educational innovations studied externally motivated change where the innovation was designed and planned by experts and where the teachers were simply expected to integrate or adapt the innovation provided to them in their classrooms. That existing research focuses largely on the top-down implementation of well-structured innovations and gives insufficient consideration to the realities and the needs of individual teachers, including: their learning as they integrate innovations in their subject area; the multiple types of changes teachers deal with in schools; the complexities of their roles in their schools; and, the implications of integrating poorly structured innovations, particularly innovations that would engage new technologies.

In order to address these shortcomings, our study investigated the process of innovation initiated, integrated and sustained by teachers and characterized by a bottom-up implementation where individual teachers organize and manage the integration of innovations in their subject area and within their own classrooms by relying largely upon their personal knowledge, skill levels, and interests. Referencing the review of literature on integrating laptop computers presented earlier in this paper, it is evident that more needs to be researched and understood about how innovations in science instruction can be made both pedagogically and institutionally successful. Given the relative scarcity of research concerning the role that teachers play in implementing innovations, studies like the one reported herein can help researchers, teachers, policy-makers, school and school system administrators better understand what can be done to enhance both the implementation and dissemination of innovations that promise to create improved pedagogy and student learning. In mapping the lived experience of teachers who work daily within the complex world of classrooms and schools, educators may understand more fully how the adoption of promising innovations can be encouraged and how the dissemination of success can be facilitated.

By building knowledge about how teachers perceive, understand, and act to integrate laptop computing in their instructional work, this paper would speak to the broader and potentially more significant issue of how the implementation of innovation can be better designed so that it can more expeditiously achieve the educational ends it would accomplish.

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