S I N G A P O R E  T A B L E T  P C  P R O G R A M  S T U D Y

E X E C U T I V E  S U M M A R Y  A N D  F I N A L  R E P O R T

V O L U M E  1 :  T E C H N I C A L  F I N D I N G S

O C T O B E R  2 0 0 5

Prepared by: Center for Technology in Learning
Marie A. Bienkowski
Geneva Haertel
Ryoko Yamaguchi
Andres Molina
Frank Adamson
Lynne Peck-Theis

SRI International
P16685
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Executive Summary</strong></td>
<td>5</td>
</tr>
<tr>
<td>Introduction</td>
<td>5</td>
</tr>
<tr>
<td>Method</td>
<td>5</td>
</tr>
<tr>
<td>Student Results</td>
<td>7</td>
</tr>
<tr>
<td>Teacher Results</td>
<td>9</td>
</tr>
<tr>
<td>Artifact Analysis</td>
<td>11</td>
</tr>
<tr>
<td>Prior Research</td>
<td>12</td>
</tr>
<tr>
<td>Conclusion</td>
<td>12</td>
</tr>
<tr>
<td><strong>Introduction and Background</strong></td>
<td>14</td>
</tr>
<tr>
<td>Background</td>
<td>15</td>
</tr>
<tr>
<td><strong>Implementing the Tablet PC Program: Views from the Principals</strong></td>
<td>17</td>
</tr>
<tr>
<td>Catholic High School Principal Interview</td>
<td>17</td>
</tr>
<tr>
<td>Motivation for Adoption: “The Whole Campus Becomes a Resource Center”</td>
<td>17</td>
</tr>
<tr>
<td>Teachers Succeed with IT Skills, Pedagogical Creativity, and Resourcefulness</td>
<td>18</td>
</tr>
<tr>
<td>Keeping Students on Task and Technical Problems Are Challenges</td>
<td>18</td>
</tr>
<tr>
<td>The School Adapts Its Curriculum, Teaching, Assessment, and School Culture</td>
<td>19</td>
</tr>
<tr>
<td>The Potential Payoff Is Worth the Risk</td>
<td>20</td>
</tr>
<tr>
<td>Crescent Girls’ School Principal Interview</td>
<td>20</td>
</tr>
<tr>
<td>Serving as a Testbed for Emerging Technology</td>
<td>21</td>
</tr>
<tr>
<td>Ensuring Success through School Planning, Industry Participation, and Parent Support</td>
<td>21</td>
</tr>
<tr>
<td>Not Just Technology: Student-Centered Instruction, Understanding What Works for the Child, and Teacher as Researcher</td>
<td>22</td>
</tr>
<tr>
<td>Assessment and Project Work</td>
<td>23</td>
</tr>
<tr>
<td>Moving on toward Exams and Forethought before Implementation</td>
<td>24</td>
</tr>
<tr>
<td>Hooking Students on Learning as They Are Hooked on Games</td>
<td>24</td>
</tr>
<tr>
<td><strong>Teaching with Tablet PCs: Views from Teachers</strong></td>
<td>26</td>
</tr>
<tr>
<td>CHS Teacher Interviews</td>
<td>26</td>
</tr>
<tr>
<td>Tablet PC Teaching: Writing, Drawing, and Envisioning</td>
<td>26</td>
</tr>
<tr>
<td>Easy Sharing of Information among Groups and Presenting Work with PowerPoint</td>
<td>27</td>
</tr>
<tr>
<td>Managing Distractions</td>
<td>27</td>
</tr>
<tr>
<td>Teachers Find Value in Weekly Sharing of Ideas on Tablet PC Use</td>
<td>29</td>
</tr>
<tr>
<td>Teachers Enjoy Instant Access, Organization, and Convenience</td>
<td>29</td>
</tr>
<tr>
<td>Next Steps: Assessment and Overcoming Technical Problems</td>
<td>30</td>
</tr>
<tr>
<td>CGS Teacher Interviews</td>
<td>30</td>
</tr>
<tr>
<td>Tablet PC Teaching: Internet Research, Analyzing Data, and Telling Science Stories</td>
<td>30</td>
</tr>
<tr>
<td>Supporting Project-Based Work and Capturing Students’ Interests with Multimedia Presentations and Anytime Learning</td>
<td>31</td>
</tr>
<tr>
<td>Teachers Find Strategies for Controlling Classroom Behavior</td>
<td>32</td>
</tr>
<tr>
<td>Teachers Find Support in Sharing Sessions and Understanding Learning Styles</td>
<td>33</td>
</tr>
<tr>
<td>Students See the World through Data on the Internet and Connect Related Resources</td>
<td>35</td>
</tr>
<tr>
<td>Instant Assessment of Student Learning</td>
<td>35</td>
</tr>
<tr>
<td><strong>Learning with Tablet PCs: Views from Students</strong></td>
<td>36</td>
</tr>
<tr>
<td>Student Focus Groups</td>
<td>36</td>
</tr>
<tr>
<td>Students Make the Most out of Their Tablet PCs</td>
<td>36</td>
</tr>
<tr>
<td>Students Access the Internet from Anywhere</td>
<td>36</td>
</tr>
<tr>
<td>Students Easily Create Presentations and Artwork</td>
<td>37</td>
</tr>
<tr>
<td>Organizing Information Is No Longer a Chore</td>
<td>37</td>
</tr>
<tr>
<td>Learning Is More Interesting and Collaborative</td>
<td>39</td>
</tr>
<tr>
<td>Working in Groups Face-to-Face and Remotely</td>
<td>39</td>
</tr>
<tr>
<td>Challenges: Form Factors and Classroom Distractions</td>
<td>40</td>
</tr>
</tbody>
</table>
Tables and Figures

Table 1: Relationship of Classroom Practices, Convenience and Frequency of Use, Exposure, and Positive Experiences with the Tablet PC to Students’ Self-Report of Outcomes 9
Table 2: Relationship of Classroom Practices, School Membership, IT Proficiency, and Positive Experiences with the Tablet PC Applications to Teachers’ Self-Report of Outcomes 11
Table 3: Technology at Home: A Proxy for Technical Sophistication 41
Table 4: Teachers’ Rating of Their Proficiency in IT Before the Program Started 41
Table 5: Survey Items Constituting the Teacher Attitude Variable 42
Table 6: Survey Items Constituting the Student Learning Improvement Variable 43
Table 7: Regression Results for Attitudes toward Tablet PC Use and Student Learning Improvements 47
Table 8: Regression Results for Perceptions of Learning for Students of Different Prior Achievement Levels 48
Table 9: Survey Items Constituting the Student Attitude Variable 51
Table 10: Regression Results for Variable “Helps in Learning in Subjects” for CHS and CGS Students 55
Table 11: Regression Results for “Learning Behaviors” for CHS and CGS Students 56
Table 12: Regression Results for “Attitudes toward using the Tablet PC” for CHS and CGS Students 57
Table 13: Regression Results for “Time and Efficiency” for CHS and CGS Students 58
Table 14: Different Ways in Which Students Plan to Use the Tablet PC in the Future 60
Table 15: What Students Like about Using the Tablet PC 61
Table 16: What Students Dislike about Using the Tablet PC. 62
Table 17: New Ways Tablet PCs Could Be Used to Improve the Learning Experience at School 63
Table 18: Pre and Post Literature Lesson Plan for the Book Roll of Thunder, Hear My Cry 68
Table 19: Pre and Post Lesson Plan for Geography: Land and Water Reclamation 68
Table 20: Pre and Post Lesson Plan for Mathematics: Coordinate Geometry 68
Table 21: Pre and Post Lesson Plan for History: Fall of Singapore and Japanese Occupation 69
Table 22: Pre and Post Lesson Plans for Science: Atoms, Molecules, and Ions 69
Table 23: Pre and Post Lesson Plans for Chinese Language: Descriptive Writing 69

Figure 1: Overview of mp2 (Source: Singapore MOE) 15
Figure 2: Conceptual Framework for the Analysis of Teacher Responses 46
Figure 3: Conceptual Framework for the Analysis of Student Responses 54
Figure 4: Fun with Construction Example 66
Figure 5: Mind Book Example with Ink-based Text Input Box Shown 66
Executive Summary

Introduction

Nations are investing in technology-rich environments to boost student achievement and to confer an internationally competitive advantage on their students. Countries realize that these more competitive students will help them attain important economic goals. One country’s high-achieving students, in particular, have captured the interest of the international education and business communities. Singapore ranked #1 out of all participating nations in the TIMSS 2003 international comparison of mathematics and science test scores at both the 4th and 8th grade levels. Recognizing that innovative and creative thinking is also required to remain competitive in the global marketplace, Singapore is deepening its curriculum to emphasize these attributes. One essential facet of their plan is to incorporate technology into all parts of their educational system.

Two emergent themes in technology-based education are one-to-one computing and mobile computing. The technology that may well best support these kinds of computing is the Tablet PC. In addition to possessing the same capabilities as other PCs (typically including wireless Internet access), these notebook-sized computers have a reconfigurable screen (in some forms) that allows the user to employ them as a flat notebook that can be written on with a special stylus. Unlike PDAs, the screens are not touch-sensitive so they can be leaned on for support while writing. The Tablet PC “inking” feature includes advanced handwriting recognition, and the stylus can be used to operate the computer. By repositioning the screen, the Tablet PC can be used as a regular laptop with keyboard. (The Tablet PC also comes in a slate form that cannot be used as a laptop.) Tablet PCs are thought by some to combine the best features of laptop computers with the ease of use associated with writing. To date, tablet computing has not caught on widely in those nations that include IT in their K-12 education plans. However, in Singapore, two schools have taken the bold step of transitioning a whole grade level (13- to 14-year olds) to Tablet PC computing in advance of its adoption by the entire school.

SRI International (SRI), in partnership with Microsoft Asia Pacific, is studying the use of Tablet PCs in these two high-performing schools: Crescent Girls' School (CGS) and the all-boys Catholic High School (CHS). Each school has approximately 250-340 secondary students who own Tablet PCs and who have been using them for 5 (CHS) to 12 months (CGS) on their wirelessly connected campuses. Both schools are using Tablet PCs in all subjects and have some of their textbooks completely digitized.

Our study has four objectives: (1) to describe the Tablet-PC-based teaching and learning environment, (2) to develop a conceptual framework that relates school and classroom variables associated with Tablet PC use to student learning and motivation, (3) to identify factors that affect implementation at the classroom and school levels and (4) to understand the alignment of this one-to-one computing program with the Singapore Ministry of Education's vision of "Thinking Schools, Learning Nation."

Method

In 2005, SRI collected and analyzed data that described the Tablet PC program in these two Singapore schools. This mixed-method study used surveys and interviews to document
students’ and teachers’ perceptions and use of Tablet PCs and qualitative analyses of Tablet PC applications and lesson plans as evidence of how the applications are actually being used. For students, we gathered self-report data about frequency of use, experience with Tablet-PC-specific applications, perceptions of convenience and efficiency, changes in classroom practices, and effects on their learning and motivation. We gathered similar data for teachers, as well as their lesson plans before and after the Tablet PC program. These data revealed teachers’ views of effective professional development for Tablet PC use, ease of technology use, barriers to integration of the Tablet PCs into curriculum, and changes in classroom practices and management. Teachers also commented on the effects of the Tablet PC on learning and motivation for students of different achievement levels.

A conceptual framework was developed that articulated the influences at the classroom and school levels that were related to Tablet PC use and the ways in which Tablet PC use affected student learning and motivation. The following research questions were proposed:

- To what extent do teachers and students report that use of Tablet PCs improves students’ learning of content? Does the influence of Tablet PCs vary for students at different achievement levels?
- In what ways does the use of Tablet PCs affect the strategies that students use when doing their schoolwork? Does it improve the efficiency with which students complete their schoolwork?
- What are teachers’ and students’ attitudes toward the Tablet PC?
- What is the prior IT proficiency of teachers and students participating in the study? How technologically savvy are their households? How does this savviness affect their attitudes?
- How often do students and teachers use the Tablet PC in school and at home, and for what purposes? How convenient is the Tablet PC to use?
- How much exposure do students have to the specialized Tablet PC applications that have been created as tools for learning? What are students’ and teachers’ opinions about these tools?
- How did classroom practices change with the introduction of this integral technology? How much more access did teachers have to resources for teaching as a result of using the Tablet PC?

Open-ended questions on the teacher and student surveys were used to elicit novel uses of the technology, as well as likes and dislikes about the Tablet PC. Quantitative and coded responses from the surveys were triangulated with the interview data to confirm results. Summary statistics generated from the survey were used to anchor discussions of the teacher and student results with the school stakeholders. These discussions, in combination with the results of the analyses, indicate that the program is viewed as timely and very promising for Singapore’s education future.
In these schools that have adopted a mobile, one-to-one learning approach, all students and teachers have a portable tablet computer with a full-sized, writable screen and keyboard; specialized applications that take advantage of drawing, pointing, and handwriting; wireless Internet access anywhere on campus, at home, and in many businesses frequented by students; and an almost paperless experience with digitized texts and electronic retrieval and submission of schoolwork. Added to these affordances is the change enabled by students’ ownership of the Tablet PC: they can appropriate it and use it broadly to support many of their learning practices. In the following paragraphs, we will highlight findings from the teacher and student data that characterize the teaching and learning environment that surrounds Tablet PC use at CHS and CGS.

**Student Results**

**Students’ Use of the Tablet PC.** The 12- to 16-year-olds in this study rated their IT proficiency before the Tablet PC implementation as average to very good. They use their Tablet PCs often to search for information, take notes, write reports, and access information posted by their teachers on a school portal. They also use the Tablet PC to work on group assignments, sharing files and data via close-range infrared transmission or USB flash drives. These creative students also enjoy creating presentations and artwork, and in one of the schools, the halls and administration conference rooms showcase student Manga art.

**Attitudes toward the Tablet PC and Students’ Reports of Learning.** Acceptance and appropriation of the Tablet PC by students and schools take time. Thus, we would expect to see differences between CHS (5 months use) and CGS students’ (12 months use) self-reports of learning and attitudes toward the Tablet PC. As expected, there were differences between student perceptions of Tablet PC impact at the two schools. Perceptions of how the Tablet PC helps learning, improves learning quantity and quality, and increases efficiency differed significantly between the schools. In contrast, the students’ attitudes toward the Tablet PC were similar at the two schools; regardless of how long students had been using the Tablet PC, students on average had positive attitudes toward the technology.

For the students at CHS, who had less exposure to the Tablet PC, having a positive experience with the Tablet PC applications was the single significant predictor that emerged from our analysis for how the Tablet PC helps in learning. In contrast, at CGS, which had a lengthier implementation, several variables predicted how the Tablet PC helps learning in content areas. These predictors included: an increase in positive classroom practices, frequency of using the Tablet PC for learning support practices, and total exposure to applications. For students who are earlier in their implementation (i.e., CHS students), challenges with using tablet applications may overshadow any other changes that occur in or outside of class. In contrast, CGS students knew (through visits by industry and government personnel) that they were at the vanguard of the Tablet PC implementation in Singapore and knew that their advice was being solicited for tools and applications. So, for CGS students who not only used the Tablet PC longer but also felt themselves at the forefront of a sweeping change in teaching and learning with technology, more factors influenced their views on learning with technology.

**The Importance of Convenience.** The convenience of this technology was an important factor for students at both schools. The convenience of the Tablet PC affected the ways the students used the technology, their attitudes toward it, and the efficiency with which they were
able to complete their schoolwork. Students’ attitudes about the Tablet PC were also related to their experiences with it in the classroom setting and their experiences with the applications.

**Tablets and Learning Practices.** Learning independently and producing high-quality work relate positively to convenience and frequency of using the Tablet PC for learning practices, such as searching for and organizing information and preparing presentations. For experienced students, an increase in positive classroom experiences (such as researching a topic on their own and presenting their work in class) and positive experiences with Tablet PC applications were also significant factors for positive learning behaviors such as independent and high-quality work. The importance of learning practices such as searching and taking notes suggests that there is a strong role for basic tools and functions that cut across all subjects and that the future of Tablet PC use in classrooms should not be focused narrowly on applications that are specialized for particular subjects.

Table 1 shows a summary of the findings from the correlational analysis of the student survey responses.
**Table 1: Relationship of Classroom Practices, Convenience and Frequency of Use, Exposure, and Positive Experiences with the Tablet PC to Students' Self-Report of Outcomes**

<table>
<thead>
<tr>
<th>Influences on Student Outcomes</th>
<th>Improves Learning in Content Areas</th>
<th>Increases Efficiency in Schoolwork</th>
<th>Positive Attitudes of Students toward the Tablet PC</th>
<th>Improves Learning Quantity, Quality, and Independence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Positive Classroom Practices (e.g., research beyond textbook, independent work, presenting work, interaction with teachers)</td>
<td>CGS***</td>
<td>CHS***/CGS***</td>
<td>CGS***</td>
<td></td>
</tr>
<tr>
<td>Convenience of Tablet PC</td>
<td>CGS***</td>
<td>CHS***/CGS***</td>
<td>CHS***/CGS***</td>
<td></td>
</tr>
<tr>
<td>Frequency of Tablet Use to Support Learning (e.g., note-taking, searching, organizing, presentations)</td>
<td>CGS**</td>
<td>CGS**</td>
<td>CHS***/CGS***</td>
<td></td>
</tr>
<tr>
<td>Total Exposure to Tablet PC Applications</td>
<td>CGS**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Experiences with Tablet PC Applications</td>
<td>CHS***</td>
<td>CHS**/CGS***</td>
<td>CGS**</td>
<td></td>
</tr>
</tbody>
</table>

**Teacher Results**

While students eagerly embrace technology in school that helps them prepare for the future and that makes learning more fun and exciting, teachers face the challenge of accommodating a significant shift in their professional practice. Teachers at these schools accept the shift as inevitable, recognizing that students must acquire 21st century skills to succeed in today’s global marketplace. Teachers’ accommodations to information technology can be characterized in several ways—in some cases as replacement: using PowerPoint and a video projector instead of overhead transparencies and projectors. In this case, teachers are conducting instruction the same way and covering the same curricular content. In other cases, their accommodations are evolutionary: teachers select student work to present to the class, using a classroom network and a remote control application. The teachers use new and varied

---

1 Note: *** = estimated coefficient statistically significant at < .01 level and ** = estimated coefficient statistically significant at < .05 level.

2 The following were not correlated with outcomes in the analysis: using the Tablet PC for skills for learning and for entertainment/collaboration/communication, prior IT proficiency, and technology-savvy home.
types of content, but the students do not engage in radically different learning experiences. In still other cases, the accommodation is revolutionary: teachers replace handouts and worksheets with an Internet-based WebQuest. In this case, the teachers change both the content and instructional activities in which students engage, and they expect a higher-level learning outcome from the students.

As with many innovations, how teachers use the Tablet PC is influenced by a number of factors. Below we highlight some of the factors that were related to the CHS and CGS teachers’ implementation of the Tablet PC program.

**Using Tablet PCs with Students of Varying Achievement Levels.** Despite the inevitability of IT adoption in education, teachers’ perceptions about how helpful the Tablet PC was for improving student learning differed, depending on whether the students were considered traditional, low-achieving, or high-achieving. For high-achieving students, teachers perceived learning to occur regardless of the presence of the Tablet PC. For both traditional and low-achieving students, however, teachers reported that these students improved their learning if positive classroom practices improved and if teachers had more positive experiences with the Tablet PC applications.

An interesting note for low-achieving students is the difference by school. The CHS teachers believed that the Tablet PC had a negative effect on low-achieving students. In particular, they believed that low-achieving students’ participation in class, behavior, motivation, and other behaviors were negatively influenced by the presence of the Tablet PC. This perception may have been due to the changes required in classroom management because of the Tablet PC. Teachers may believe that lower-achieving students have a more difficult time acclimating to learning with the Tablet PC especially if they are not self-motivated and disciplined towards learning.

**The Role of Teacher Experience and Tablet PC Use.** Teacher perceptions of how much the Tablet PC supports innovative teaching and learning and their attitudes toward the Tablet PC are influenced by their experiences with applications. These factors are also influenced by an increase in positive classroom practices such as students exploring a topic on their own and researching beyond their textbooks. In the interviews, more experienced teachers reported on the fundamental change in their profession that the use of a school portal may cause. Portals are public and encourage reuse of materials and continuous improvement. This publicity may be uncomfortable for experienced teachers who are used to the privacy of the classroom, whereas it may give new teachers a significant boost in their entry into the teaching profession by providing resources for review, a venue for feedback on their lesson plans, and facilitating networking with their peers.

**Length of Implementation.** It would not be surprising to find a difference between the schools based on the different lengths of implementation. One might expect to find that early implementers (CHS) were overwhelmed by the new technology or that those further into their implementation (CGS) were experiencing an “implementation dip” (Fullan, 2001). However, there was no significant difference between the schools in teacher beliefs about the impact of the Tablet PC on overall student learning or teacher satisfaction with the technology. Studies of innovations in educational reform indicate that a drop in performance and satisfaction with the innovation may occur as teachers become more aware of the limitations of the innovation,
but also that change leaders can steer reform efforts through these dips (Fullan and Miles, 1992). It would be interesting to explore why this dip did not occur in the present program.

Table 2 shows a summary of the findings from the correlational analysis of the teacher survey responses.

**Table 2: Relationship of Classroom Practices, School Membership, IT Proficiency, and Positive Experiences with the Tablet PC Applications to Teachers’ Self-Report of Outcomes**

<table>
<thead>
<tr>
<th>Influences on Teacher/Student Outcomes(^4)</th>
<th>Teachers’ Self-Report of Outcomes(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Positive Classroom Practices (e.g., research beyond textbook, independent work, interaction with teachers)</td>
<td>***</td>
</tr>
<tr>
<td>School</td>
<td>***</td>
</tr>
<tr>
<td>Teacher IT Proficiency before the Tablet PC Program</td>
<td>**</td>
</tr>
<tr>
<td>Teacher Positive Experiences with Tablet PC Applications</td>
<td>**</td>
</tr>
</tbody>
</table>

\(^3\) Note: *** = estimated coefficient statistically significant at < .01 level and ** = estimated coefficient statistically significant at < .05 level. Parentheses indicate a negative correlation.

\(^4\) The following were not correlated with outcomes in the analysis: total exposure to Tablet PC applications, Tablet PC use for teaching, amount of Tablet PC use, and technology-savvy home.

**Artifact Analysis**

Industry partners were an important part of the Tablet PC program at these schools. Hardware, networking, and textbook companies participated, and software companies worked with CGS to generate ideas for Tablet PC educational applications. Thus, in addition to the more standard productivity applications that are useful for capturing, locating, organizing, and presenting information, applications in subjects such as mathematics, Chinese language, and science were developed and used at one or both schools. Software for classroom management and information organization was also developed and used in these schools. School portals for information sharing were used at each school to promote sharing among school staff and communication among the administration, teachers, and students.

Use of these applications was evident in lesson plans. Comparison of a selection of lesson plans before and after the program showed that more interactive, creative, and independent work was required of students in those lessons using the Tablet PC.
Prior Research

To determine the state of research in the area of one-to-one and mobile computing, a literature review limited to several key articles was conducted. The articles selected for review were mostly primary research studies that examined the relationship of use of Tablet PCs (or laptops) and one-to-one computing in educational settings. We identified 21 studies, 7 of which were judged to be directly relevant to the current study.

This selective literature review revealed that although many articles have been written about the use of Tablet PCs and one-to-one computing, relatively few of these articles are data-based, and only a small number of them go beyond anecdotal reports by users. Most studies conducted to date used survey, interview, and informal observation at sites as the key methodology. The most popular outcomes studied were student motivation and engagement, student learning, student and teacher attitude toward technology, and classroom practices. Very few studies of the impact of Tablet PCs on student learning have been conducted to date (although there have been several studies of the effect of one-to-one computing on student learning).

Results of this early research on Tablet PCs reveal positive effects on student motivation and engagement, praise of the Tablet PCs’ portability, increased potential for distractions in the classroom, increased evidence of collaboration among students and between students and teachers, more frequent teaching of information and communication technology (ICT) skills in context, less frequent reliance on textbooks as the means of delivering content, increased pace of lessons, and greater richness and variety of instructional content presented. Teacher professional development is considered a critical element for the successful implementation of any one-to-one computing technology, including the Tablet PC. Ownership of the Tablet PC is a strong determinant for how much learning students and teachers report. To date, Tablet PCs have been used generally to support and to extend instruction; researchers have concluded that it is still too early for them to be used in ways that truly transform day-to-day life in classrooms.

Conclusion

CHS and CGS students at this grade level (entry into secondary school) made good use of the Tablet PCs. Convenience of the Tablet PC was a major factor in students’ reports of learning in various subjects and their efficiency in doing their schoolwork. Convenience also helped in the appropriation of the technology into many learning practices. Frequency of use in learning activities was significantly related to learning across various subjects, student attitudes, and efficiency in schoolwork. As schools transform their teaching practices to tablet computing, special attention should be given to integrate the Tablet PC into the curriculum and teaching across as many subjects as possible. From these results, it is clear that the more students used the Tablet PC across the school day, the better they were able to use it as a learning tool. In the open-ended questions on the survey, students identified several issues that concerned them, including battery time, weight of the Tablet PC, technical issues, and physical discomfort carrying the tablet.

Interviews with teachers brought out the importance of having time to create quality lessons that use the Tablet PC, and schools should consider providing professional development on how to integrate Tablet PCs into the classroom at different stages in the implementation. The
professional development should address different needs. When teachers first start using the Tablet PC in school, the needs are about basic use, application use, classroom management, and hardware questions. As teachers become adept at Tablet PC use, the needs change to understanding how to use the Tablet PC in specific lessons, and the focus of professional development should be on integration of the technology into the curriculum to teach traditional, high-achieving, and low-achieving students. Teachers should be given an opportunity to reflect on their experiences at regular intervals and discuss their experiences with their more experienced peers.

Frequency of use in teaching and learning activities and positive experiences with the Tablet PC applications were significantly related to teacher perceptions of student learning and attitudes. As schools integrate the Tablet PC into everyday teaching and learning, focus should be placed on giving teachers enough professional development throughout the school year, enough planning time to integrate the Tablet PC into teaching and classroom management, and time to share their experiences and resources with colleagues. In addition to placing value on providing a smooth and fluid teacher experience with the Tablet PC applications, emphasis should be placed on how the school administration implements the initiation of teachers, and teachers should be prepared for potentially unsettling changes in their teaching practices.

Note: SRI wishes to thank the staff and students at Catholic High School and Crescent Girls’ School for their participation. Special thanks go to the CGS principal, Mrs. Lee Bee Yann, and Vice Principal, Mr. Gary Tan, and the CHS principal, Mr. Lee Hak Boon, and IT director, Mrs. Oh Wee Ming. Mr. Anwar Chan of the BackPack.NET Centre provided valuable assistance during the data collection and insights into the Singapore school system that greatly aided the analysis of the data.
Introduction and Background

Nations are investing in technology-rich environments to boost student achievement and to confer an internationally competitive advantage on their students. Leaders in countries across the globe realize that these more competitive students will help them attain important economic goals. One country’s high-achieving students, in particular, have captured the interest of the international education and business communities (Friedman, September 16, 2005). Singapore ranked #1 out of all participating nations in the TIMSS 2003 international comparison of mathematics and science test scores at both the 4th and 8th grade levels. Recognizing that innovative and creative thinking is also required to remain competitive in the global marketplace, Singapore is deepening its curriculum to emphasize these attributes. One essential facet of their plan is to incorporate technology into all parts of their educational system.

Advances in information and communication technologies (ICT) make this plan workable. Three notable trends that are influencing teaching and learning worldwide are one-to-one computing (Mitchell Institute, 2004), mobile computing (Roschelle et al., 2004), and wireless access. In some instances, as in networked classrooms, these trends are converging in ways that are transforming the classroom environment and possibilities for student engagement (Roschelle, Penuel & Abramson, 2004a).

The technology that may well best support these kinds of computing is the Tablet PC. In addition to possessing the same capabilities as other PCs (typically including wireless Internet access), these notebook-sized computers have a reconfigurable screen (in some forms) that allows the user to employ them as a flat notebook that can be written on with a special stylus. Unlike PDAs, the screens are not touch-sensitive so they can be leaned on for support while writing. The Tablet PC “inking” feature includes advanced handwriting recognition, and the stylus can be used to operate the computer. By repositioning the screen, the Tablet PC can be used as a regular laptop with keyboard. (The Tablet PC also comes in a slate form that cannot be used as a laptop.) Tablet PCs are thought by some to combine the best features of laptop computers with the ease of use associated with writing. To date, tablet computing has not caught on widely in those nations that include IT in their K-12 education plans. However, in Singapore, two schools have taken the bold step of transitioning a whole grade level (13- to 14-year olds) to Tablet PC computing in advance of its adoption by the entire school.

SRI International (SRI), in partnership with Microsoft Asia Pacific, is studying the use of Tablet PCs in these two high-performing schools: Crescent Girls' School (CGS) and the all-boys Catholic High School (CHS). Each school has approximately 250-340 secondary students who own Tablet PCs and who have been using them for 5 (CHS) to 12 months (CGS) on their wirelessly connected campuses. Both schools are using Tablet PCs in all subjects and have some of their textbooks completely digitized.

Our study has four objectives: (1) to describe the Tablet-PC-based teaching and learning environment, (2) to develop a conceptual framework that relates school and classroom variables associated with Tablet PC use to student learning and motivation, (3) to identify factors that affect implementation at the classroom and school levels and (4) to understand the alignment of this one-to-one, mobile computing program with the Singapore Ministry of Education's vision of "Thinking Schools, Learning Nation."
**Background**

In 2002, the Singapore Ministry of Education (MOE) released its second visionary plan for technology in education. This master plan II for Information Technology (IT) in Education (mp2) identifies global, national, and school-level goals (Figure 1) for IT to achieve the goal of “Thinking Schools, Learning Nation” for Singapore. The plan puts forth specific goals for IT:

mp2 adopts a holistic approach to the use of IT. The pupil, teacher, curriculum and assessment and environment (at school, national and global level) are essential parts of the education system. IT will be used to enhance teacher-pupil relations; interaction, peer support and collaboration among learners (pupil-pupil, teacher-teacher); and interaction between learners and the wider community. – *Singapore MOE*

mp2 emphasizes engagement with learning material and real-world experience as the basis for learning. It sets forth the standard that IT will be pervasive and effectively used. Requiring that IT be pervasive suggests the need for multiple ways to integrate it into many classes and activities. Effective use implies that both students and teachers have enough knowledge and skills about IT, and sufficient exposure to IT, that they can implement new approaches without too much effort. Furthermore, the mp2 vision stresses customized education, which means that IT must support the teacher in recognizing students’ interests and thinking, adapting to them, and providing them with resources to pursue learning on their own.

![Figure 1: Overview of mp2 (Source: Singapore MOE)](http://www.moe.gov.sg/edumall/mp2/mp2_framework.htm)

---


In 2003, Singapore’s Infocomm Development Authority (IDA, the government agency charged with broad oversight of Singapore’s information and telecommunications infrastructure) launched, with Microsoft, the BackPack.NET initiative. With a focus on education, this program seeks to drive research and development in information technologies. Broadly conceived as having four foundational pillars, this initiative comprises (1) testing pilot programs in schools, (2) supporting regional technology companies in developing capabilities to create applications for tablet computing, (3) designing and conducting research and development in education, and (4) maintaining a showcase/laboratory for technologies called “Classroom of the Future” (COTF). To date, BackPack.NET Centre has established the physical COTF, has worked with 4-5 industry partners to develop novel applications for the Tablet PC, has assisted in the implementation of tablet computing in several Singapore schools, and is participating in studies of the implementations. Our study focuses on two of Singapore’s top-performing schools, Crescent Girls’ School (CGS) and Catholic High School (CHS) which are participating in the BackPack.NET Centre.

These pilot schools provide rich environments in which the implementation of “cutting-edge” IT can be pursued at the same time as they seek to reform their approach to teaching. After studying ICT trends, these schools chose to adopt one-to-one tablet computing for students and teachers on a wireless campus. Even though tablet computers cost slightly more than laptop computers, the school administrators believed that the unique form of tablets over laptops would be more engaging and would better suit the varied learning styles of their students. Driven by the national vision of IT in education, these schools were able to motivate their staff, parents, and students to embrace the change at the scale of an entire class (i.e., grade) level.

To understand how the adoption had occurred, we conducted a survey of students and teachers, along with structured interviews of students, teachers, and the principals of the schools. In this way, we could document Tablet PC use, as well as student and teacher satisfaction with the technology. In the following sections, we describe these school environments through the views of their principals, teachers, and students.

---

Implementing the Tablet PC Program: Views from the Principals

In this section, we present each school’s vision as obtained from interviews with each principal. First we present the Catholic High School results, then those from Crescent Girls’ School.

Catholic High School is a government-aided all-boys school serving primary and secondary students. CHS has a competitive admission process and a long history of educational excellence, as recognized by its national awards (MOE Thinking Culture and Academic Value Added) and its 100% pass rate on the secondary exit exams. The secondary school is autonomous and therefore has additional flexibility to implement novel education programs. The Tablet PC program at CHS was implemented in January 2005 at the Secondary Two level. Out of the nine classes in the Secondary Two grade level that were eligible, eight classes adopted the program. There were 293 students who participated in the study in May 2005, ranging from 13 to 16 years old.

Catholic High School Principal Interview

Mr. Lee Hak Boon was interviewed in May of 2005. Mr. Lee has been the principal at CHS since 2003. He was accompanied during the interview by his director of Information Technology, Mrs. Oh Wee Ming. Mr. Anwar Chan from the BackPack.NET Centre was also present. Interview questions are listed in Appendix A in Volume 2 of this report.

Motivation for Adoption: “The Whole Campus Becomes a Resource Center”

Mr. Lee believes that the Tablet PC gives a whole new definition to teaching and learning that inspires excitement and enthusiasm in the students and teachers. He related as an example a 3D model of a chemistry simulation that shows atoms and particles moving about. When the temperature increases, bonding occurs. With one picture, he states, “you can see it all.” He views tablet computing as a new wave in pedagogy and learning styles and is confident that only minor problems will be encountered during the adoption. Mr. Lee sees the Tablet PC as very different from a laptop. It is so much more versatile—one cannot “ink” on a laptop. Eventually, he sees voice recognition as making transmission of information in digital form even easier.

“We want to transform our students into independent learners…More and more the learning should be the responsibility of the students.”

When asked what motivated the school to adopt the Tablet PC, Mr. Lee replied, “We want to transform our students into independent learners…More and more the learning should be the responsibility of the students…” In contrast to the constraints imposed by having computer and Internet access be inside a computer lab, now, with one-to-one, wireless, and mobile computing “the whole campus becomes a resource center.” In this environment, the school can help students find and make meaning from information, and thus students become prepared for the challenges of a world where use of IT is ubiquitous. Viewing students as independent learners means that they can be given a topic—for example, tsunamis—and they will find information and put facts together. Students can access factual knowledge about tsunamis, as before, and also now can see pictures, video-clips, news stories, and personal accounts on the Internet.

Students using IT have access to thousands of pieces of information, in contrast to text-based
sources of information, such an encyclopedia, where they might find only a page or two of information. These students moreover, will know about the impact of tsunamis on the lives of others. “So, the learning, the scenario, the landscape has already changed, with the Internet so we cannot wait and not tap on these vast resources.”

Companies will be interested in CHS graduates, Mr. Lee believes, because they will be different from other students. A CHS graduate who has learned using a Tablet PC, he asserts, will be much more knowledgeable because he will have been accessing information from sources other than books. More importantly, if you put a challenge in front of these future graduates, they will have a capacity to tap into vast resources to solve it. Having greater capacity to access vast resources of knowledge produces greater productivity. In addition to having learned the knowledge base of a discipline, such as law, more versatile workers will have varied IT skills, which will permit them to import data, write computer programs, and the like.

**Teachers Succeed with IT Skills, Pedagogical Creativity, and Resourcefulness**

Teachers at CHS were trained in two ways to use the Tablet PC. First, they learned how to deploy it pedagogically, infusing technology into curriculum. For teachers to use a tool well, they need to see how it can support teaching and learning. Next, they were taught how to use the tablet computer and applications. Training in pedagogical use was done with a combination of small-group lessons conducted by the head of the IT department at the school (Mrs. Oh), training by personnel from the companies that developed the software applications used on the Tablet PC, and sharing sessions among teachers in the same department. The sharing sessions are where the pedagogical use was addressed.

Mrs. Oh served as an important intermediary between the software developers, technology trainers and the teachers. Teachers who are keen to develop courseware or applications can be linked up to software developers to bring their ideas into realization. Teachers did not always find the training useful, in one training for a Tablet PC application the teachers had no hands-on component, and consequently, they were neither ready to implement nor were they able to get interested in using the application.

After they are given the basics, it is ultimately up to the teachers’ creativity and resourcefulness to make the best use of the technology. Mr. Lee sees adoption of the Tablet PC in teaching as not too different from having to prepare to teach a new subject: at the beginning there are a lot of preparation hours, and as time goes by you have the resources ready at hand based on this prior work.

**Keeping Students on Task and Technical Problems Are Challenges**

A challenge for CHS, at 5 months into implementation, was controlling the students’ use of the Tablet PC as a learning tool. The teachers were concerned with the need to make sure that students were on task and not being distracted to using other applications, such as instant messaging, during lesson time. Mr. Lee’s response to this was threefold: (1) stop the problem with control (i.e., block Internet sites and check machines periodically for illegal software); (2)
use Virtual Classroom, a software application that lets teachers see (on the teacher’s computer) what students are doing on their Tablet PCs in the classroom; and (3) educate students about developing good habits. The school seeks to help the students understand that good management of their time and their learning will help them throughout their lives. Students need periodic reminders to develop the habit to stay on task; he did not foresee any challenges in making this happen.

At this early stage in the adoption of wireless tablet computing, there are still technical problems and people are still getting used to the machines. It takes longer to accomplish any sort of task when teachers and students are not yet adept with the tools. But the work is worth the effort: Mr. Lee evoked a comparison with the previous situation of students and teachers working in separate computer labs on an occasional basis with full-time possession of a mobile computer plus campus-wide Internet access.

**The School Adapts Its Curriculum, Teaching, Assessment, and School Culture**

**Curriculum.** Rather than needing to spend curriculum time learning IT, Mr. Lee felt that eventually teachers would be able to cover more material, for example, showing pictures can mean you don’t have to spend time explaining. The more resources there are at a teacher’s disposal, the more opportunities students have to grasp concepts. IT makes learning more efficient and saves time. In addition, students learn knowledge inquiry and develop process skills for learning on their own. For independent learners, learning a subject is no longer bounded by the curriculum time in the classroom.

**Teaching.** Teachers will become more like facilitators. Rather than having a teacher just impart knowledge, now students can ask more open questions and answer them by using more resources. Although teachers still cover the basic concepts, students are encouraged to look out for ways to go beyond the basics. With this view of teaching, “The whole learning process has taken on a new dimension.”

Mr. Lee did not articulate a specific new approach to teacher professional development, but he felt that teacher motivation had changed with the introduction of the Tablet PC. Before the implementation, teachers had to use learned strategies and tactics to motivate students. Now he felt that their capabilities could develop sufficiently that they would be able, for example, to design a game for learning. Teachers want to motivate students, and one way of doing so is to tune in to what students like, and “they like computers.” Therefore, teachers are motivated to use technology because it motivates their students. Teachers want to upgrade their IT skills because they realize that there is so much they can do with the computer. The Tablet PC can become so easily available, just like SMS [Short Message Service] on many mobile phones, that it changes daily life.

**Assessment.** In this new dimension of learning, assessment is not simply a regurgitation of what a student is taught. Using project work as an example, it is apparent that everyone has access to the same wealth of information and so quality now depends not on knowledge but on process skills and how students apply them. Working in groups, students can learn from their peers and measure their performance against each others’. At the same time, more traditional assessments can be accelerated. For example, teachers can use the Tablet PC to pose questions...
at the end of class and get an instant count of who understood the material instead of waiting for a test.

School Culture. Tapping into students’ motivation to learn with computers creates more passion for learning. The school culture used to be to impart knowledge from a purveyor—now there is a community of learners learning from one another: peers, parents, even people in other countries. Perhaps most insightful is this final observation about the changes brought about by the introduction of one-to-one, mobile, wireless computing in CHS. The quest for learning now can be immediately satisfied with ready access to digital resources, and this satisfaction reinforces the learner.

The Potential Payoff Is Worth the Risk
When considering adoption for CHS, Mr. Lee felt that even without a 100% probability of success, the potential payoff was worth the risk. For this program to succeed at other schools, the school must be willing to take on new challenges and must be able to get the buy-in from the parents through group and individual meetings. Parents may prefer the traditional way of education, but if they have confidence in the school, they will agree to changes. Parents must also be supportive and willing to purchase the Tablet PCs as a learning tool. Mr. Lee acknowledged that cost could be a deterring factor for some schools. He felt that other schools could adopt the CHS model of teacher training, but the school administration considering adoption of tablet computing needs to provide leadership to ensure success. The school must also have the right people, such as a good IT director and technical support staff, who aspire to make education even better.

Crescent Girls’ School Principal Interview
Crescent Girls’ School is an autonomous government all-girls school that serves secondary students. The school has a number of special programs that are funded by MOE (including being an IT incubator school) and these programs support the school in innovating with its curriculum. At CGS, teachers have won national awards (Outstanding Youth in Education, Outstanding Science Teacher, Caring Teacher), the school ranks high on national surveys (e.g., on a School Climate Survey it was highly rated on characteristics such as flexibility, responsibility, rewards, standards, clarity, and team commitment), and the school has won national awards (e.g., Singapore Quality Class, Singapore Innovation Class, and MOE Thinking Culture).

CGS was the first school in Singapore to implement a one-to-one Tablet PC program. The program was implemented in July 2004 with Secondary Two students and expanded to Secondary One students in 2005. There were 344 students who participated in the study from Crescent, ranging from 13 to 16 years old. We employed the same methodology at this school as was followed at CHS.

Mrs. Lee Bee Yann was interviewed in May 2005. Mrs. Lee has been the principal at CGS for 7 years. Mr. Anwar Chan from the BackPack.NET Centre was present. The interview questions are listed in Appendix A.
**Serving as a Testbed for Emerging Technology**

CGS has a culture of pervasive IT. It is a testbed for emerging technology and a research and development school. They adopted an *m-learning* (mobile learning) approach (Lehner & Nöskabel, 2002) to IT after conducting a review of the external IT and business environment, talking with parents and industry contacts, and considering the school’s vision and culture. They concluded that, for the “Net-geners” that they are teaching, the fun and excitement of technology must be harnessed for learning. “It’s cool to be smart” exclaim the millennials at CGS (Howe, Strauss & Matson, 2000).

CGS has the advantage of being an IT demonstration school, designated so by the Singapore MOE. At the end of each year, the school staff reflect and consider what is next for their program. In June 2003, their focus was mobile learning. From June to December 2003, an IT committee and school leadership met to consider plans, and all staff at the school reviewed the capabilities of the Tablet PC. At a brainstorming session, 30 computer applications for the subjects taught at CGS were proposed.

Reactions to the proposal were obtained in January and May 2004 as administrators met with parent focus groups. Parents raised practical concerns, such as where the computers would be stored during PE class and how they could not become a distraction. Yet, overall, parents agreed with the idea of using Tablet PCs, and so a decision was made to implement the technology.

**Ensuring Success through School Planning, Industry Participation, and Parent Support**

After the deliberation described above, the Tablet PC program at CGS went through a carefully planned rollout with built-in factors for success. First, the youngest cohort of students were selected for participation with the rationale that they would have the most time to benefit. (These students are also the farthest from the high-stakes secondary school exit exams.) Next, planning for the implementation included teacher professional development. Teachers allocated Tuesday of each week to spend time for the tablet-using teachers to gather and reflect on their experiences. Teachers and the school administration identified the need for staff such as trainers, system administrators, A/V specialists, aides, and teacher mentors. As early as October 2003 and into May 2004, teachers went through training in the Tablet PC, and a pilot trial of 7 to 10 teachers was conducted during this time.

Industry participation was a key factor in the CGS adoption, especially in helping the Tablet PC work broadly across the curriculum. CET Technologies helped with procurement and NTUC Income with insurance. Intel helped wire the campus. Fujitsu gave the students and teachers a discounted price for the tablets. IDA provided support and staff resources. Microsoft provided training to staff and students, as well as supplying an IT audit package and integration support. Finally, supporting the move to an all-digital education, Pearson, Marshall Cavendish, and SNP Panpac converted some of the standard Secondary One textbooks into e-books. Popular e-Learning provided a viewer for the digital textbooks.

Parents were overwhelmingly supportive of the school’s efforts. Initially, the school administration wanted to implement a treatment-control experimental design for the implementation to be able to rigorously establish effectiveness, but the principal was so
deluged with parents wanting their daughters to be in the “treatment” group that the school decided to adopt across all classes in one grade level.

Parents’ concerns about missing computers meaning missed lessons prompted the school to have loaner laptops that the students can use if theirs breaks down, and the parents’ concerns about security led to the school’s designing and building special Tablet PC lockers. At 6 months into the program implementation, CGS presented an accountability report to parents.

**Not Just Technology: Student-Centered Instruction, Understanding What Works for the Child, and Teacher as Researcher**

CGS strives toward an open culture in which all participants can discuss their beliefs on how to effectively educate children and to arrive at a set of common understandings. An open culture such as this requires a certain level of trust but will eventually, Mrs. Lee believes, lead to a shared vision and set of practices.

One of CGS’s common understandings is based on the realization that times have changed both inside and outside of school, and that this change requires a transformation from teacher-directed to student-centered instruction. Mrs. Lee reported this as the “greatest transformation” she has seen in her 7 years as principal. Instruction used to be “chalk and talk”: the teacher lectured with little student participation. Now, there is a greater emphasis on the child as a learner, and teachers have to understand what constitutes effective learning and change their teaching strategies accordingly. “Having taught,” she asserted, “does not equate to having learned.” At the same time, teacher professional development has changed to keep up. In the past, training had meant equipping teachers with the skills to deliver lessons—teaching them how to make a lesson interesting and how to manage a classroom. Now the focus is more on helping them understand what works for the child.

Part of the impetus to move from teacher-directed to student-initiated is because students no longer wait for teachers to give them knowledge but find it out for themselves. Teachers feel a pull from the students to adopt technology-based learning programs. “I think the Tablet PC has been instrumental in this movement, because with ready access to information, students may know much more than the teacher on a particular area and students will come back with information and…the teachers would have to keep themselves updated with the latest information out there.”

Another common understanding is a need for sensitivity to students’ learning styles. The school is studying this topic to learn how to ascertain whether a student’s profile matches a teaching style (Yeap & Low, 2000). The motivation is not so much to ensure an exact match as it is to see that understanding what works well for students is important information for teachers to help them tailor lessons and make learning more effective.

A final common understanding is the view of teacher as researcher, and Mrs. Lee elaborated on her ideas of developing teachers into researchers in this way. She sees
the first stage as understanding what the important aspects are that one needs to consider in doing research—such as validity and reliability—so that teachers can, for example, design a valid questionnaire to evaluate whether a teaching strategy is effective. The goal is to do more than equip teachers with the skills to do research but to foster an evaluative mind-set to help them become more confident and certain about their classroom practice. This way, they can put the research lens on their own practice. To achieve this goal, CGS devoted 30 of its 100 hours of yearly teacher training time to helping teachers think as researchers.

The view of teachers as researchers is admittedly very revolutionary, and it sets very high expectations on CGS teachers. Yet Mrs. Lee sees CGS teachers as “holding it together” now, after having gone through different stages. In the early stages, the work was about getting everyone to share a common vision for what to achieve for the school. Having done that, the school went through several assessments by external organizations. These organizations were asked to come in and evaluate the school, not just from an educational perspective but also from an industry standard view. Once these reviews were completed, the school staff had the confidence that they had all the right systems in place, and then they could pursue the next stage of development and go both deeper and to greater heights.

Mrs. Lee acknowledged that teachers sometimes do feel the strain of having to learn something so rigorous, and she and her staff try to inject fun into trainings. She mentioned that their next training would be held in a resort in Malaysia, and that she intended to bring a lot of fun and games to it, such as friendly competitions and shopping. During other trainings, she has told jokes and done exercises and dancing. Nevertheless, her motivational words for teachers are direct: at the end of their careers, their students should be able to tell them they were the best teacher they had ever had.

When it came to the reality of planning lessons that used the Tablet PC, Mrs. Lee deliberately did not set very difficult targets for teachers. In fact, when the school started on the Tablet PC program, she set the expectation that each teacher would create just one lesson per semester to harness the functionality of the Tablet PC. If each of the 20 teachers in the Secondary Two cohort contributes one lesson, then 20 lessons can be shared by everyone each semester. Framing the changeover in this way makes the problem feel tractable and builds a sense that everyone is working together.

Assessment and Project Work

Course content at CGS is dictated by the government syllabus and the need to prepare students for the major exams that are taken after Secondary Four. Assessment is still largely done on paper, as are the standard national exams. However, Secondary One and Two students in the Tablet PC program have experienced other forms of assessment: instant quizzes on a Tablet PC classroom response system, multiple-choice questions, and recording devices that tape speech, music, and singing. Teachers can access these assessments digitally, and often, teachers can grade students on processes they have demonstrated even if the right answer is not obtained. Notwithstanding these alternative forms of assessment, the school views assessment with the Tablet PCs as an area still to be investigated.

In addition to teaching the content from the syllabus, the school seeks to teach Secondary One and Two students through project work. Groups of three to four students engage in a 6-month
project and to solve their problem, they get information from the Internet, talk to experts, and combine interdisciplinary content. Students have come up with very interesting projects, some involving the external community and many relying on the Tablet PC’s drawing and presentation features. This project work provides a different type of information about student performances than the paper-pencil examinations described above.

**Moving on toward Exams and Forethought before Implementation**

Mrs. Lee talked about how she expected that the Tablet PC would be used as students move to upper grades, where exam preparation becomes of critical importance. Secondary Three and Four students spend a lot of time reviewing for these exams, and consequently she sees a change in the way that the Tablet PCs will be used. Students will use the tablet more as a library for organizing information for review and to access digital copies of practice papers and exams. At these higher grades, teachers will be using more sophisticated kinds of software to teach more difficult concepts. Although introduction of technology at higher secondary grades could be seen as risky, given the importance placed on exams, Mrs. Lee sees little risk, given her belief in children’s capacity to absorb and learn new things.

Students are admitted to CGS on the basis of the high scores they attained upon leaving primary school. Given this special student population, Mrs. Lee was unsure how this program would work in other settings. It worked at CGS because of the culture of innovation at the school, the caliber of the students, and the willingness (even insistence, perhaps) of the parents. Given another school setting, the unique characteristics of that school would have to be considered before a successful implementation could start. Use of the Tablet PC might be different at a school with normal/technical students who might be less academically inclined but good with their hands and who like to create and design. Someone running such a school would have to consider the available applications (such as those in use at CGS) and whether they would apply to their students. A program like this, she believes, should not be implemented without careful forethought and planning.

**Hooking Students on Learning as They Are Hooked on Games**

Over the 7 years during which Mrs. Lee has been principal, she has seen many changes and has observed that each year brings new opportunities and surprises. The mind-set of her staff and students was such that they could capitalize on these opportunities, and the developments excited the students very much. She sees two areas as holding great interest for students in the future: gaming and virtual reality. Students become glued to arcade games and are passionate about the mastery of these games: if this passion could be translated to something worthwhile and meaningful, then it could be a powerful and motivating force. CGS would like to understand the psychology behind the addictive nature of games: could this be translated into an addiction to learning? If so, it would revolutionize education. Another area of potential is virtual reality, and CGS is already exploring applications with a university partner. How can enriching experiences be developed for content such as the biology of the human body? It may seem far-fetched to imagine having expensive technology at the school for immersive virtual experiences, but now they are exploring simulations of museums, buildings, and the like and seeing how these affect learning. Next to gaming and virtual reality applications, the applications developed at CGS for the Tablet PC in 2004/2005 will seem “as ordinary as turning on a light switch.”
In line with this forward-looking view of education, Mrs. Lee reported that the school staff are very excited to be part of this “revolution.” At the same time that they see immense possibilities, they also admit that achieving the vision was not easy and that they had braved many uncertainties. Much was at stake: they had to be sure how this was going to affect the education of the students. What is not apparent from the present state of the program is all of the thinking, conversations, and networking with partners that took place and helped to avert a possible disaster caused by implementing without thinking through the educational value. First the administrators and teachers had to see the value; then they had to inspire the teachers and then the parents to come on board. She recalled a time early on when there was a press write-up on the program and the public reaction was negative: “It’s a waste of money to put some expensive equipment in the hands of 12-year-old!” Given this kind of criticism, the school needed to be able to answer the critics as to why they were doing certain things—to defend their stand on changing the way this new generation of students learns. So the school staff has gone through many challenges, but looking at the outcomes—the changed atmosphere in the school around expectations for success and excitement at the prospect, and the teachers’ excitement about going into research and feeling professional—the feeling overall is that it has been a worthwhile journey.

“I think for us we are very clear that this is our vision, and that is, we want to provide the kind of nurturing environment for innovation to take place and for our students to become ladies and leaders of tomorrow. So…the ability to cast your eyes far into the horizon is very, very important in the whole culture of the school.” The school administration is always looking ahead and beyond just tablet computing with special applications, and teachers have learned to do so, too. The school is an “education enterprise,” and the education of the child is paramount. “To us, the implementation of the Tablet PC happens to be an impetus coming in at the right time, providing us with the necessary conditions for the school to move forward.” For whatever is done at CGS is done with the goal of nurturing the whole child.
Teaching with Tablet PCs: Views from Teachers

To understand how the Tablet PC implementation affected teachers, we interviewed three teachers from each school. Teachers were selected by the school administration, and interviews were conducted in May 2005. The interviews lasted from 40 to 60 minutes, and teachers were assured of anonymity of their responses. At CHS, teachers of science, Chinese, and history were interviewed. At CGS, teachers of science, geography, and mathematics were interviewed. The interview questions are presented in Appendix A in Volume 2.

In our interviews, we spoke about challenges and affordances of the Tablet PC in teaching and learning. Challenges and affordances were also elicited in some of the survey questions, so in this section we also include selected information from the teacher responses to several open-ended questions on the survey. These survey questions were as follows:

1. Please describe how the Tablet PC changed the curriculum and state for which subject.
2. Briefly describe the most useful training you have participated in and how it was delivered.
3. What training or assistance do you need to further integrate technology into the curriculum?
4. Briefly describe 5 different ways in which you will use the Tablet PC in your teaching.
5. Briefly describe 2 things that you like about using the Tablet PC.
6. Briefly describe 2 things that you dislike about using the Tablet PC.

This section and the one following (presenting students’ views) include references to Tablet PC and education-specific applications used by the teachers and students. A brief description of these tools can be found in the section titled “Tablet PC Applications and Lesson Plan Changes” on page 64.

CHS Teacher Interviews

The teachers interviewed at CHS had a range of teaching experience from very experienced (18 years) to 4-7 years of experience. Teachers with experience (older and hence further removed from experience with technology at a young age) may have initially felt unsure about the Tablet PC implementation, but they also felt an urgency to upgrade their technology skills in response to a pull from the students. They seemed to feel it was natural and not intimidating that the students knew more about technology than they did. These teachers accepted that children are fast learners who want to learn with and about technology. Consequently, it made sense for the school to adopt technology in the classroom.

Tablet PC Teaching: Writing, Drawing, and Envisioning

Examples from CHS teachers of what can be done with the Tablet PC include teaching descriptive writing in Chinese by showing a picture, asking students to imagine how a writer could have described it, then asking them to write a description on the Tablet PC. Alternatively, students listen to descriptive writing then draw the scene by using the stylus and inking. Using a classroom management tool called Virtual Classroom, teachers can capture drawings and other student work to share with the whole class. Teachers can also type up notes
for students to download via Virtual Classroom, and students can add to the notes as the teaching occurs.

In History, students are given political cartoons and asked to mark them to highlight irony, sarcasm, etc. The results can be shared by way of Virtual Classroom. Students can then create their own cartoons (using inking) and share these cartoons with others to see whether they are interpreted as intended.

Another example (proposed but not yet implemented by the teacher) was teaching Chinese by manipulating digital text: leaving blank sections in a digital text for fill-in-the-blank, rearranging paragraphs, and deleting extra paragraphs. Interestingly, this was something that the teacher who described it used to do with paper and can now envision doing with the computer.

In science, students have looked at animations on Web sites that show atoms, molecules, digestion, and ways to balance chemical equations. Students also take quizzes at the sites, and, when appropriate, they are free to follow links on these sites to other material. No standalone science applications are used, but the teacher is interested in interactive simulations. She reported that she wants to expand the kinds of applications used in science class and is looking for ideas to share from other schools. She reported a discussion with the science textbook company in which she and other teachers requested a molecule simulation that they thought was easily achievable but the company reported as difficult to implement.

**Easy Sharing of Information among Groups and Presenting Work with PowerPoint**

Group work was seen as being easier with the Tablet PCs because students can do their own work of gathering information from the Internet and then share it by using a flash memory drive or infrared beaming of files among Tablet PCs. During class time, students are not encouraged to share by crowding around a Tablet PC because that can lead to distractions, but teachers reported that instead student work can be easily projected for all to see.

Teachers reported that they presented content with PowerPoint and that they would prefer their students to use it also. Teachers felt positive about PowerPoint because students use more pictures and drawings in their presentations. It also can bring teachers’ presentations to life so that students can see a concept immediately.

In one class, students conduct 3-week-long-projects, e.g., on an external event of their choosing that affects Singapore. Interestingly, when the teacher did not specify final presentation format, students used various ways to present the information: text in OneNote or Word or mind maps drawn with the stylus. During the sharing of the final presentations, students could see the different learning styles that were in the classroom, and teachers could get ideas about ways to present information to these students.

**Managing Distractions**

At the outset, some teachers felt apprehension about adoption: how can teachers manage students and their learning when they
are faced with screens instead of faces? Teachers developed classroom management strategies such as walking around more to check that students are focusing on the given tasks, standing in the back of the classroom more often than they had done before, and having students put their Tablet PC in tablet mode when using it in class. Teachers also discourage students from working on several tasks at once so they do not get distracted. Control is valued, and with large class sizes (i.e., 40 students) and secondary students (i.e., ages 12-16) teachers are less inclined to conduct lessons that are more open to student control. This cautious approach is to be expected with teachers early in the implementation phase of a new technology in the classroom.

When teachers enter the classroom (teachers, not students, change classrooms in Singapore schools), students are using their Tablet PCs (typically in laptop mode). Teachers initiate their lessons by asking students to shut the Tablet PCs, which puts the computers in a sleep mode. Teachers have learned how to detect whether a student is distracted and have devised various stratagems for countering distraction (having them shut down the computer, standing at the back of the classroom, or using Virtual Classroom). On the survey, some teachers reported difficulties with knowing whether students are on task. Until teachers have more experience with using the Tablet PC in class, they are likely to encounter such difficulties.

CHS teachers know that the same attraction that can lead to distraction can be harnessed for learning. Teachers believed that students found the lessons that are done on Tablet PCs to be more interesting. For a teacher who teaches a self-professed “boring” subject, technology is seen as a way to make lessons more interesting and engaging. Ideas such as crossword puzzles, newspaper reports, and other tools offer something more interesting than reading from a book. However, they also felt that the classroom could be “more messy” when students were working together on the Tablet PCs conducting projects during class time.

Not all teachers and students are tech savvy (e.g., some student struggle with tasks such as reading PDF files). Teachers felt that skill development on the Tablet PC would be useful for some students. At the same time, teachers also reported that students can pick up technology skills from their friends very quickly.

Wireless access to the Internet is available throughout the campus, although gaming and instant messaging are blocked to ensure that the students access the network exclusively for learning purposes. At CHS, the administration conducts periodic checks on the students’ Tablet PCs to ensure compliance to copyrights and to check that no illegal software is installed on the computer.

Overall, these teachers believed that if students do not engage in sound learning practices—staying on task, learning independently, and seeking resources for learning—then the Tablet PC will not add value to their education. Students who can learn on their own are the best match for this one-to-one technology.
*Teachers Find Value in Weekly Sharing of Ideas on Tablet PC Use*

Teachers at CHS received training on tools (from CHS staff or outside trainers) during the holiday before school began and had weekly sharing sessions among teachers at one grade level for the first 3 months. (The rate of the sharing sessions slowed, once teachers felt more comfortable using the Tablet PC.) During these sessions, teachers shared resources, lessons, and design work, and talked about how to use Tablet PCs in the classroom. As expected, the formal training just taught them the tools, and the sharing sessions showed them how to use their creativity to develop starter ideas into good teaching materials.

At CHS, all Secondary Two teachers are teaching with the Tablet PC, and teachers were asked to have about 50% of their lessons using the Tablet PC. On the survey, one teacher from each school reported that preparing lessons to include the Tablet PC was time-consuming. The sharing sessions, it was felt, only generate ideas, and the work of turning them into a lesson still takes time. Classroom preparation takes up more time, one needs to come up with more creative ways to teach, and just how much more time preparation takes depends on how adventurous a teacher wants to be.

Teachers want more advanced training in how to use the Tablet PC effectively in the classroom. One described the training they had received to date as “elementary to intermediate” and thought that to really have good learning outcomes, more advanced training was needed as was time to develop more advanced lessons. Teachers in one department have tried dividing up lesson creation (e.g., by sections of the textbook) but at the same time, some did not want to use these lessons unchanged. Teaching is “quite personal,” and one needs time to adapt materials for student interest or ability. The only substitute they could think of for more time was having teaching aides.

On the survey, teachers reported that they needed assistance with ways of effectively integrating the Tablet PC and they wanted to know what lessons other teachers had learned about how to integrate the technology into their curriculum. They also wanted more on-demand technical assistance for how to use software and how to create games and fun activities. In addition to wanting to learn from other teachers who were successful in using the Tablet PC in the classroom, these teachers wanted practical advice for their specific subjects.

Nevertheless, teachers see their access to resources as expanding through the archival nature of the school portal. For example, finding quality Web sites can be time-consuming. Sharing the load throughout a department and building up a repository stored for all to use in the school portal was seen as a potential benefit of the program.

*Teachers Enjoy Instant Access, Organization, and Convenience*

With wireless access, information is available at once, and teachers can easily read newspapers and Web sites to stay current. On the survey, teachers predominantly selected easy access to information as a positive feature. They also liked the multimedia features (photos, animations, and movies). Teachers see an advantage of the Tablet PC over desktop computers in the ready access to information: “[Usually] you can’t bring the world to the classroom, whereas now you can.”

Another advantage of the Tablet PC, over desktop computers is the ready information access: “[Usually] you can’t bring the world to the classroom, whereas now you can.”
Teachers enjoy the convenience of accessing the Internet from their classroom versus going to a computer lab.

The teachers liked using the Tablet PC to organize class and student information, check students’ homework, write with the stylus, and annotate items like poems with ink. Teachers liked knowing when a student submitted work to the school portal and being able to check online whether homework was done. Two of those interviewed also mentioned the convenience of going paperless, and convenience was also mentioned by several on the survey.

Teachers liked the convenience of the digital textbooks. Although some courses teach more content than is in the digital textbook (so it can be limiting to rely on the textbook), with a digital textbook, a student can see more real-life phenomena via media such as animation, sound, and 3D views. One teacher felt that visual learners would especially benefit from the Tablet PC.

Students can be creative with the Tablet PC: one teacher saw students using mind-maps and inking as they studied for tests. Because everything is on the Tablet PC in an accessible form, making connections among information stored in different places is easy. Having work be all-digital also means that teachers can mark up student work by highlighting or annotating it online. They can easily show homework or class work to the whole class to highlight good or weak points. Sometimes there were technical problems with SharePoint (such as corrected assignments getting lost), but teachers felt the benefits outweighed inconveniences.

Next Steps: Assessment and Overcoming Technical Problems

No changes in student assessment were reported, except for giving instant quizzes via the Virtual Classroom response feature and showing work to the class for critiques. Sharing student work with the class is seen as a way to give an appreciation for how others approach their work. Students are still assessed by their sharing of project results and, in some cases, assignments that involve oral questioning.

Technical problems with the network were a source of frustration, and the survey responses echo this frustration. Breakdowns can “almost render teaching useless,” and the unpredictability of the breakdowns adds to the stress levels. Previous practices, such as walking around during lectures, are now not possible because of the tethering of the Tablet PC to the video projector.

CGS Teacher Interviews

The teachers interviewed at CGS had a range of teaching experience from very experienced to brand-new. Teachers with experience may have initially felt (and in some areas, still feel) intimidated, but they also had already begun to see positive effects, and that reinforced their belief in the technology. The younger teachers saw nothing unusual about being asked to teach with technology, and they were very excited by the prospects.

Tablet PC Teaching: Internet Research, Analyzing Data, and Telling Science Stories

CGS staff were working with more Tablet PC-specific applications, so their examples made reference to these. One class studied pollution sources and types, first by listening to and
reading content and then participating in a project in which they were given a researcher’s role. Being given an authentic role excited the students and motivated their map-reading exercise. They followed a map of the school to find places that could be the source of pollution, researched these sources at a Web site, and then eagerly shared what they found out with their class.

The application Fun with Construction was developed with significant input from teachers at CGS, and this participation motivated its use. “We have experimented, since we started this project, we have been experimenting with this, because it’s something new, after all, it was developed by us and our partners, so we want to see how it will work for teaching and learning.” A teacher used it to teach statistics by having students visit Web sites, collect data, and then draw statistical charts with the application. The students’ reaction was positive and they liked the ability to erase wrong answers and to draw and color their charts. This statistics lesson was made more compelling through the use of real data. Students enjoyed using the Internet in class to access authentic data: “…it’s a real-life learning experience.”

One experienced teacher saw a major improvement over the computer work she had seen in the past. Her example was a lesson (which she had done previously without the Tablet PC) to teach the digestive system. She knew that if she only lectured, the topic would not be very interesting. So, after a lecture on the idea of a transport system, she got them excited about the adventure of an indigestible seed that travels through the digestive system. Arming them with Internet sites linked to digestion, she told them to make a narrative of the journey of the seed. In contrast to classes without the Tablet PC, these girls produced very creative stories, and because of the stylus and inking they were able to draw everything easily. At the end of this project, it was very easy to have a gallery walk and look at the result on each Tablet PC. She and the students picked a few of the better ones and projected them for everyone to see. The students are open to critiques of their work, and “they laugh a lot.” Overall, the teacher found this lesson engaging and fun both for her and her students.

One teacher envisioned an activity for teaching rotational symmetry, in which she first does a lecture to introduce the concept and then has the students go to different parts of the school to find examples. The found object can then be sketched or a picture taken. This approach will make the learning more interesting by applying the ideas to authentic objects.

**Supporting Project-Based Work and Capturing Students’ Interests with Multimedia Presentations and Anytime Learning**

Students at CGS participate in a special project-based course under the supervision of a mentor teacher. Students collaborate around the Tablet PC for their project-based learning, and every week there is one session in which the group members work together on their projects. Teachers have observed students many times putting the tablets together to collaborate via infrared beaming of files. At other times, students discuss work online from different parts of the campus. The mentor teachers do not have to be present to answer questions but instead can be e-mailed with questions. Teachers are not bothered by this easy access; rather they feel it is good that they can serve every student’s needs. Previously, one teacher felt bad if she kept
students waiting after school to talk to her. Now she can ask them to post a message, in this way, she feels not only that she can help them but that she gets to know the girls better.

In this new approach, teachers still present information in the form of lectures to their classes. Now, however, the possibilities for ways of presenting information have opened into rich media: text, animations, and video. Multimedia is important because some teachers present content for the first 10 to 15 minutes of class before Tablet PC-based activities are begun. Teachers said that students look forward to the lessons and find them more interactive. Before teachers had Tablet PCs, they could present interesting PowerPoint presentations, during which the “girls can only stare at us.” Now presentations are uploaded before class into the school portal so that the girls can download them for themselves, following along and annotating them as they deem necessary. Teachers have seen students doing this, and they believe that, as a result, the information is now more fixed in the students’ memories.

Student projects too are now seen as more media rich, with presentations being more colorful, more animated, and containing more pictures and data. Teachers see that the Tablet PC encourages students to be more creative, daring, and innovative. Now that students share their projects with the rest of their class more regularly, it has changed their work in a significant way. They are more particular about the quality of their work because it will be shared, and many want to showcase their talents.

Students are encouraged to learn on their own, and they have ownership of their learning now. Even now, when a Web site is introduced, they want to go beyond the material their teachers want them to learn. Some already want to learn concepts that are in the Secondary Three or Secondary Four. It is easy to see their motivation to engage with interactive multimedia materials online. Using media that contains interactive content gives students a different understanding of what they are trying to learn because they now get quasi-hands-on experience. As an example, one teacher found a Web site on rotational symmetry where students can drag points on an object around to see how it looks as it is being rotated. Furthermore, students can continue to explore Web sites such as these at home, so learning becomes an “anytime” activity.

**Teachers Find Strategies for Controlling Classroom Behavior**

Experienced teachers said that the classroom feels different with the Tablet PCs. Some teachers feel that engagement in learning makes the management easier. For example, if a new topic is introduced using a special WebQuest—“they [the students] become very well-behaved, very focused. It’s easier to manage.” Instead of being bored in a classroom where a teacher lectures them, now students are motivated and excited by the Tablet PC applications, and this keeps them from being distracted. This idea about easier management is not echoed across the board by teachers, and, in the survey, some teachers reported difficulty in keeping students from distraction. This could be more about teaching experience than it is about technology. Experienced teachers have stratagems to encourage good behavior, and, surprisingly, they do not need to tell students when to use the Tablet PC and when not to. The students in their classes are frequently taking notes and making mind-
maps and need frequent access to the machines. Instead of using a technical solution, one teacher recounted how she will go over to a distracted student or will send a “spy.” Other teachers have classroom rules, created with the students’ help, that outline consequences such as payment of $1 for the first infraction and confiscation of the Tablet PC for future ones.

“One teacher reported that parents may be concerned about distractions and so teachers could use Virtual Classroom to monitor their work and remind them of the rules if needed. This teacher reported using Virtual Classroom to check on students’ activities three days out of five, and also reported using it to block undesirable sites and to switch off the wireless connection when needed. For another teacher, the Tablet PC can be used to develop students’ character by teaching them that using the Tablet PC is a privilege. Another teacher agreed, stating on the survey: “Students, teachers, and parents [are] asking for external measures to curb playing of computer games when the only way to stop this would be change of mind-set of students.”

Teachers Find Support in Sharing Sessions and Understanding Learning Styles

Teachers valued the weekly, half-hour sharing sessions that are done within their departments. By seeing the good lessons that others have done with the Tablet PC, they can save time by modifying a lesson for their own use. Teachers at CGS reported that the annual IT seminars were useful, and they reported receiving a lot of support from e-coaches and teaching assistants. Teachers felt that the weekly sharing sessions helped those teachers who were not so sure about using applications such as Virtual Classroom. Their training for this program began well before the Tablet PC project was rolled out, and learning OneNote, Journal, inking, PowerPoint, and MS Producer helped them prepare teaching materials. For training on applications, hands-on work followed by a project was felt to be most useful for learning. One teacher recalled having to produce a lesson using MS Producer after learning it. Then she noted it could be put into Microsoft Learning Gateway (MLG, the CGS school portal) for retrieval later. For her, this training had a practical application in that she got to use her project later, and the lesson was not done just for purposes of the training.

For teachers who have prior experience with technology and are comfortable using it, the Tablet PC experience was fun and exciting, and one in which they were exploring possibilities together with the students. Senior teachers who initially felt inexperienced with the applications now are comfortable using them. Teachers who are very comfortable with technology report employing advanced tools such as Flash to create quizzes and study aids. The advantage with an interactive application, they feel, is that students can know right away if they get the answer correct. Tech-savvy teachers see the benefits for applications such as MS Producer in cases requiring self-directed learning. For example, in case of an infectious disease breakout during which students are not able to come to school, students can download lessons that teachers have created using MS Producer and study at home. These interactive lessons could also help weaker students who can go through lessons at home at their own pace.

Teachers didn’t all feel that the use of the Tablet PC made their preparation more work. For brand-new teachers everything needs to be prepared. However, there is also the sharing made
possible by the archival feature of a tool like the school portal, Microsoft Learning Gateway. Because the shared document space can be accessed only by a known pool of colleagues, teachers have a sense that it is safe to place their ideas there. At CGS, all resources for all grade levels have been collated and uploaded to MLG, and everyone, teachers report, has been very forthcoming in sharing, building on, and improving them.

...some teachers reported that it was not very difficult to adjust to the Tablet PC based on their prior experience with other technology, one reported that it was “a lot of work for me to perfect my instruction.”

Teachers can use the Tablet PC to easily organize whatever they have created previously for later adaptation and differentiated instruction, e.g., to make it more or less challenging. It is easier to prepare lessons this way than on transparencies. The Tablet PC is used to organize lessons also, with teachers using MLG to save their own lessons and to access department resources. In discussing how the program has changed the way teachers work with each other, one reported that previously “we tend[ed] to be loners, suffering in misery; now we help each other.” Now, because different people have different abilities, they benefit from working with each other, especially young teachers. New teachers have a special advantage in that they will not need to become overwhelmed looking for resources.

At the same time as some teachers said that it was not very difficult to adjust to the Tablet PC based on their prior experience with other technology, one reported that it was “a lot of work for me to perfect my instruction.” Computers were previously used to present with PowerPoint, but not in a very interactive way, just “chalk and talk.” Now teachers feel they have to think of more interesting lessons to challenge students.

Understanding more about students’ learning styles helped teachers to think about new ways of teaching and to respect others’ ways of learning. The Tablet PC aids adaptation in that materials are now easier to change than transparencies. Teachers realize that they themselves may learn from diagrams, or that compare and contrast helps some students understand better. Teachers are glad to learn from their students, and one reported incidental learning experiences, such as learning to cut and paste interesting diagrams. They realize that, just as they tell their students, learning is such that people learn from each other. Becoming comfortable with ideas such as differentiated learning and learning communities is part of the shift in teaching at CGS from a teacher-centered approach to a student-centered one. One experienced teacher, reflecting on the changes in her students, said “I can only facilitate their learning, and one day they will overtake me.” This was not her view 5 years ago. At that time, she reported, “I was quite dogmatic: you are the student; I am the teacher.” Now the locus of control in the classroom has shifted. When asked what the impetus for this change was, this teacher reported that it was the girls because “they are eager learners.”
Students See the World through Data on the Internet and Connect Related Resources

Teachers are able to search the Internet for real data sources, which are important in subjects such as geography. By looking at different information sources, students can see the different ways people interpret data and see how arguments can arise around issues such as global warming. Textbooks present only one perspective and with easy access to the Internet in the classroom, students can tap into various sources to substantiate their claims. “It actually helps them to think about issues which are global as well as local issues: instead of just ‘these are the concepts, these are the facts, and then just stop.’” Teachers feel that they can teach students beyond the level presented in their textbooks. Using the Internet, teachers present sites, and curious students invite teachers to look at sites that they have found. This process keeps the class much more involved in learning.

It actually helps them to think about issues which are global as well as local issues: instead of just ‘these are the concepts, these are the facts, and then just stop.’

Teachers felt that students liked to read from the digital textbook. Students use the textbook as reference but rely on the teachers’ PowerPoint presentations for content. The textbook also provides homework and the ability to work through examples.

In using the digital textbook, teachers note that they can use the projector to highlight different parts and students can “follow along.” Any resource (Web site, PowerPoint presentation, video, document) can be linked to a paragraph in the textbook. When studying, students can use the textbook as a jumping-off point for access to related materials.

Instant Assessment of Student Learning

At the end of every chapter in their textbook, students get worksheets with cartoons, graphs, or references to passages in the text. Alternatively, something may be projected and students answer questions related to it. A teacher knows what they have learned by how they apply their knowledge to these questions. Virtual Classroom is also used to give surveys and get an instant response about what students have learned. Teachers can also send files or messages through Virtual Classroom, and at least one teacher uses it weekly. If a student sends a message just to the teacher, she can reply just to that student or share the response with the whole class.

Another teacher also uses Virtual Classroom to learn the percentage of students who did not understand a lesson and may choose to teach a concept again in a different way depending on the results of the poll.

Teachers have had to make some adjustments in their lesson preparation, classroom teaching, and assessment. Sharing with their colleagues gives them a benefit in preparation time and their own learning. Motivated by the need to keep education interesting, they use multimedia and interactive lessons. Strategies for managing distractions are employed when needed.
Learning with Tablet PCs: Views from Students

Students at Catholic High School and Crescent Girls' School are considered among the best performers in Singapore because of the scores they have gotten on the national Primary School Leaving Examination (PSLE). Depending on the score they receive, students are placed in one of four courses of study (called “streams”) in secondary school: special, express, normal, and technical. CHS and CGS provide both special and express streams, which serve students who score at the top of the PSLE ranking.

These students, even if they lack the requisite technology skills, will generally be confident of their abilities and willing to take on new tasks. Secondary One and Two students (who participated in this study) need not yet worry about taking their “O-level” exams for entrance into Junior College or Polytechnics. Consequently, the fact that applications for learning are being developed simultaneously with the students learning them does not distress these students. Instead, this group of “very confident” (according to Mrs. Lee) students make suggestions and help shape the policies. Furthermore, they “embrace change, ride on changes, and come out on top” (Mrs. Lee). At CGS, the first group of students showed the right attitudes to be early adopters: they did not expect everything to be ready and wanted to be part and parcel of the development. Their principal, Mrs. Lee, thinks that this attitude “…augers well for them when they move on to the workplace—where things are always changing and they have to adapt to new technology very rapidly.”

Student Focus Groups

To obtain a better understanding of how students feel about using the Tablet PCs, five students from each school were interviewed as part of two focus groups. The students were selected by the school administration.

Students Make the Most out of Their Tablet PCs

Students like to surf the Internet for both school and personal use. They like communication via e-mail, instant messaging (IM), and blogging, although blogging sites are blocked (at least at CGS) so that they cannot be read at school. E-mail and IM are used for talking about homework, as well as for social purposes: students reported forgetting what their assigned homework was (even with the organizational tools offered by the Tablet PC and the school portals). Students like to create art and especially mentioned ArtRage as of value in offering many different functions that are well suited to the Tablet PC. Although students still may draw on pencil and paper, sharing their artwork via email or setting it as their wallpaper is a motivation for producing it in electronic form. Students also enjoy listening to music online and purchasing music for their collections. While at home, they play online games and PC games.

Students Access the Internet from Anywhere

Students mentioned using the Internet during science classes to find out more about molecular structure and the atomic elements. They reported that use of the Internet during class time is dependent on the classroom activities. They acknowledged that the information they find is variable in its value: some Web sites are easy to understand and some are hard. For accessing
the Internet, students prefer not to use tablet mode because quick access to the keyboard is important for typing search terms.

Each campus has complete wireless coverage, so that the Internet is accessible from anywhere and students reported working between classes and after school at different locations on the campus. At home, most students have a broadband Internet connection so they can continue schoolwork.

Students also report (but not so frequently) using a digital camera. This seems to be more common as a way to get personal pictures onto the Tablet PC than as a school-related activity.

**Students Easily Create Presentations and Artwork**

During classes like history and art, students can draw, and these are classes that previously didn’t make use of computers. For art class, free image editing software (GIMP) is in use at CHS, whereas CGS students reported working with Adobe Photoshop and ArtRage. These tools allow them creative expression and the ability to make an image look just as they want it to, including adding special effects. Having it in digital form means they can easily check with the teacher to see whether they are on track, and they can submit it as a finished product in digital form.

With the Tablet PC, reports are improved because students can get images to insert via copy and paste. No differences were reported in the writing process: generating, editing, revising, etc.

A CGS student spoke about presenting her project under the “Innovation Program” in front of other students. She did a project on making a product, went to another school, and presented her idea to these students. What was notable for her was the ability to ink on and highlight the presentation to draw attention to parts of it.

At CGS, Secondary One and Two students have to do a 6-month problem-based learning task. One student reported on a project to improve the school tables. She was able to draw a sketch of the desired design in PowerPoint for her presentation.

At CGS, girls participated in the Government Leaders Forum, showcasing some of the software on the Tablet PC to the country’s Ministers and showing them the different kinds of things that they had done. The girls demonstrated lessons on geography. Also, because CGS is having its 50th anniversary in 2006, an ongoing project on orchid hybridization was done, using the Tablet PC to connect to an expert for advice on growing the orchids. Using this connection, the girls reported, they could share their thinking with the orchid expert.

**Organizing Information Is No Longer a Chore**

Students like the note-taking feature of the Tablet PC. In contrast with paper, taking notes and connecting information together on a tablet is easier because everything is in the same place and in a malleable form. They pointed out that Tablet PC users never run out of paper.

Students enjoy the ability to attach a picture or video clip to notes. Documents, Web sites, or presentations that their teachers create all become starter material for their notes. This helps students feel that they are on track with their teachers. The Tablet PCs allows them to beam notes (via infrared) to other students who have missed class. Notes that are inked on during
class are later used for studying for a test. Notes are easy to organize by subject using the OneNote application. Students also take notes using Windows Journal, and they find writing on the Tablet PC easy.

Regarding paper, however, some teachers still like hard copies, and sometimes students print notes to study. Paper is still more portable than the tablet, and students worry about getting their Tablet PCs wet during bad weather or in some classes such as science labs.

Students find SharePoint and Microsoft Learning Gateway, the school portals, very easy to access and to be an aid for organizing information. They also reported liking that teachers know when an assignment is actually submitted (because the portal time-stamps submissions) because it motivates them to not delay work on assignments to the last minute.

Having worksheets in digital form is a plus for self-proclaimed “messy students” who previously misplaced papers. Students who never bothered to file papers find that clicking documents and dragging them into a folder is so easy that they actually do it and therefore keep organized. Folders for sorting digital data into subjects are used by many students, but some “messy students” retain their personality characteristics by having a large (5 MB in size from one report) folder called “Others.” Other students reported cleaning up their folders as a favorite activity while at home.

One student also liked the high visual impact of sticky notes for setting reminders: they are hard to miss when you start the machine. Alternatively, for really important messages, the desktop itself can be inked on and these messages are hard to ignore. Many students customize their desktops because the machine is personal. They may put important folders or notes on the desktop, as well as artwork and pictures.

With the Tablet PC, students don’t have to worry about misplacing a textbook and not having textbooks lightens their backpack’s weight. CHS students did not find the digital textbooks useful however, because their courses of study do not follow the textbooks and instead go beyond them, especially for science. Neither Chinese nor History uses a digital textbook. Some students did not like reading on the screen for a long time, although CGS students reported learning (and using) eye massage and resting exercises that the principal had taught them. Other students found that taking notes while reading a digital textbook was easier and more interesting.

CGS students made more use of the digital textbooks, describing the pen tool for writing notes on the book and the highlighting function for highlighting important information in the textbook. They also had used the linking feature to add in media. They gave as an example having a geography video that shows deserts that can be attached via a link to a particular spot in the textbook. These girls reported writing on their textbook whenever they read. They attach links when the teacher posts special information, or when they go online and do research for themselves. When it comes to exams, when they are revising their textbooks, “it’s much more convenient because with just one click you can get all the information.” “Save all the hassle of flipping through all your notes and everything, so it’s just one click and then you get everything, so I think that’s very good.”
one click you can get all the information.” “Saves all the hassle of flipping through all your notes and everything, so it’s just one click and then you get everything, so I think that’s very good.”

CGS students use Journal, OneNote, and Mind Book in useful ways. They liked the different templates in Mind Book and gave as an example a science lesson on the heart during which they could use a Mind Book template—a drawing of the heart—on which to take notes and label parts of the heart. They talked about making a connection between Mind Book and their text by linking from the text to Mind Book. With Windows Journal, they talked about making mind-maps. These mind-maps can be linked from a page in the digital textbook and, of course, can also be accessed when the textbook is not open.

Using OneNote allows them to organize information into subjects, for example, using dividers that separate pages of notes. Rather than searching, students organize their information into different folders and subpages; and the autosave feature helps them safeguard their work. Autosave makes transitions between using the Tablet PC and doing other kinds of work easier: when students close the Tablet PC, they do not have to worry about losing work.

Students also mentioned the voice recorder on the Tablet PC, which can record, with the teacher’s consent, what the teacher is saying. In this way, students can record a lecture for someone who is missing class or to review it themselves at home later.

**Learning Is More Interesting and Collaborative**

Students like the rich multimedia available to them and mentioned that subjects can be “brought to life” by media such as videos, and that this is more than what is normally found in textbooks. In Home Economics, they were able to watch digital videos of cooking, which helped make the learning concrete.

In learning Chinese, students reported favorable views toward writing Chinese characters on the tablet and using the Internet to learn more about the history of Chinese. They see the tablets as a vast improvement over the congested computer labs that they used to use.

Students at CHS would like to change how the Tablet PC is used and want it adopted in every subject. They want more software that replaces hard copy such as books.

CGS students believe that they “definitely have more group discussion…and that actually helps to foster class interaction” and that “there are better ties between our classmates” as a result. Through this kind of class interaction, students are able to share the different kinds of information they each have. Students are not shy about learning together and sharing mistakes. For example, if they turn in a composition through the school portal and a teacher marks it up, she can put it on the student portal, and then the students will be able to see others’ mistakes and learn from each other.

**Working in Groups Face-to-Face and Remotely**

When students are working together in groups, they can easily send information to each other such as Web sites they have found for the project. They like projects done with the Tablet PCs
because the projects garner notice for being made by IT-savvy students. The information students that obtain using the Tablet PC is much better than they could get before and it is “without bounds.” With this improved information access, both reports and presentations are improved.

Students do in-person and online discussions especially during project work. They send messages and their work to each other. With the freedom to roam anywhere to work on campus, group work can be done when needed: “We can go anywhere and meet, if our friends are not able to turn up for meetings, we can actually do the discussion online.”

**Challenges: Form Factors and Classroom Distractions**

Battery life is a challenge to the students (more so at CHS than at CGS). Students have found ways to prolong battery life, such as reducing the display brightness. Outside of school, students find that places such as McDonald’s do not have outlets (although the public library does) and that the ability of the battery to hold its charge deteriorates over time.

Students from both schools mentioned concerns with school portals’ “losing information.” They worry about teachers’ receiving their submissions and reported that assignments have been lost.

Students are well aware that teachers are on the lookout for distractions. At CHS, teachers control when the Tablet PC is used during class. The tablets are examined for games and the operating systems are modified to prevent games from being installed. Teachers will tell the students to use the Tablet PC in tablet mode to prevent them from playing games (which require a keyboard). Students find this mode inconvenient because the keyboard can be faster when taking notes or browsing the Internet.

Students understand how Virtual Classroom works but find that teachers rarely use it to look at what students are doing. Instead, they reported, teachers use their time to teach. Virtual Classroom also does not always work and can “mess up” the Tablet PC’s operation. There was a sense that CHS students were less tolerant of “mess-ups” than CGS students, perhaps because of the CGS teachers’ involvement in designing some of the applications. The teachers’ accepting attitude could be communicated to the students. At CHS, the problems with Virtual Classroom necessitate that students type URLs instead of getting them by beaming (because distance between computers matters) or getting them via Virtual Classroom.

CHS students would like longer battery life, more RAM (machines came standard with 256 MB and were upgraded to 512 MB), a faster clock speed, and more USB ports. CGS students would like a built in CD-RW drive but acknowledge that it would make the machine heavier.

Students like to do several things at once, and the modern operating system with its multiplexing feature encourages multitasking. Even though they might resist the schools’ restrictions to doing one thing at a time, they can understand that such restrictions help them focus.
Teacher Survey Quantitative Analysis and Results

Interviews with teachers and students capture only a small sample and not a wide range of opinions. Although they can provide more depth, for overall results it is necessary to capture a more inclusive set of participants. Also, we desired to look for correlations among sets of responses to be able to postulate factors for success of tablet computing programs. In this and the following section, we present the results of a statistical analysis of survey responses for teachers and students, respectively. The detailed summary statistics showing percentages of responses can be found in Appendix C (for teachers) and Appendix D (for students).

Teacher Sample

Teachers from Catholic High School and Crescent Girls’ School participated in the survey. Of the 17 teachers who participated in the survey from CHS, 59% were women, most were 26 to 40 years of age, and more than half had 5 years or more of teaching experience. (Detailed results are presented in Appendices C and E.)

Tables 3 and 4 present background information for CHS and CGS teachers. Teachers at CHS were loaned a Tablet PC for their home and classroom use, although 29% opted to purchase their machine. Only 13% of CHS teachers had no Internet access at home, and 76% rated their IT proficiency before the start of the program as average. Even though 87% of the teachers had Internet access at home (broadband or dial-up), 47% said they did not use their Tablet PC at home.

Of the 25 teachers who participated in the survey from CGS, 92% were female, more than half were 21 to 35 years of age, and about half had 1 to 5 years of teaching experience. As at CHS, teachers were loaned a Tablet PC for their own and classroom use, although only 12% opted to purchase their machine. This could be due to their already having desktop/laptop computers available—see Table 3. Even though 92% of these teachers had Internet access at home (broadband or dial-up), 44% said they did not use their Tablet PC at home. Teachers at CGS rated themselves more IT proficient (before the Tablet PC implementation began) than teachers at CHS (Table 4).

<table>
<thead>
<tr>
<th>Technology</th>
<th>Yes (CHS)</th>
<th>No (CHS)</th>
<th>Rating (CHS)</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop Computer</td>
<td>78.6%</td>
<td>21.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laptop Computer</td>
<td>60.0%</td>
<td>40.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Videogames</td>
<td>50.0%</td>
<td>50.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP3 Player</td>
<td>40.0%</td>
<td>60.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desktop Computer</td>
<td>85.7%</td>
<td>14.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laptop Computer</td>
<td>64.7%</td>
<td>35.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Videogames</td>
<td>41.7%</td>
<td>58.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP3 Player</td>
<td>60.0%</td>
<td>40.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Technology at Home: A Proxy for Technical Sophistication

<table>
<thead>
<tr>
<th>Rating</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>3</td>
<td>17.6%</td>
</tr>
<tr>
<td>Average</td>
<td>13</td>
<td>76.5%</td>
</tr>
<tr>
<td>Very Good</td>
<td>1</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

Table 4: Teachers' Rating of Their Proficiency in IT Before the Program Started

<table>
<thead>
<tr>
<th>Rating</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>15</td>
<td>60.0%</td>
</tr>
<tr>
<td>Very Good</td>
<td>9</td>
<td>36.0%</td>
</tr>
<tr>
<td>Excellent</td>
<td>1</td>
<td>4.0%</td>
</tr>
</tbody>
</table>
**Procedure**

All surveys were taken online by the teachers using their Tablet PCs. The survey administered by SRI was based on questions developed by Singapore’s Infocomm Development Authority (IDA). SRI added questions and modified some of IDA’s questions to facilitate the analysis of data. The survey was designed to elicit teachers’ views about the use of the Tablet PC, changes in their teaching practice since adoption of the Tablet PC, and impacts of Tablet PC use on student learning. SRI did not pilot the survey with teachers because it was based on IDA’s set of questions. The survey at CGS was administered by a researcher from SRI International and a staff member from Singapore’s BackPack.NET Centre. At CHS, the survey was administered by the technology director of this school.

**Measures**

**Dependent Variables**

*Attitudes toward Tablet PC use* (alpha$^8 = .89$) is a nine-item variable that assesses how comfortable teachers felt about using the Tablet PC in their classrooms. Teachers used a 5-point rating scale of *strongly disagree* to *strongly agree* to answer the questions shown in Table 5. Items with negative wording were reversed for the analysis. The higher the variable’s value, the more positive teachers felt about the Tablet PC use in teaching and learning.

*Student learning improvement* (alpha = .91) is an eight-item variable that measures teacher perceptions of student learning and learning behaviors with the survey items shown in Table 6. The larger the number, the more teachers believe that the Tablet PC helps learning.

<table>
<thead>
<tr>
<th>Table 5: Survey Items Constituting the Teacher Attitude Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like my students to learn on a Tablet PC.</td>
</tr>
<tr>
<td>I feel comfortable using a Tablet PC in the classroom.</td>
</tr>
<tr>
<td>I think that it takes a long time to finish my lesson preparation when I use a Tablet PC.</td>
</tr>
<tr>
<td>Working with a Tablet PC makes me very nervous.</td>
</tr>
<tr>
<td>I think that the Tablet PCs are easy to use.</td>
</tr>
<tr>
<td>I was given enough training in using Tablet PC.</td>
</tr>
<tr>
<td>It’s harder to manage my classroom when all students are using their Tablet PC.</td>
</tr>
<tr>
<td>It’s hard to find ways to use the Tablet PC in my classroom.</td>
</tr>
<tr>
<td>I will be motivated to use Tablet PC if I own one.</td>
</tr>
</tbody>
</table>

---

$^8$ Alpha is a measure of internal reliability—it measures how well the items can combine to form a variable.
Improved learning for students of differing achievement levels (alpha = .94 for high, .96 for low, and .93 for traditional) is an index where teachers checked whether the Tablet PC improved the outcomes for high- and low-achieving, and traditional students for the following areas:

- participation in class, preparation for class, attendance, behavior, motivation, engagement, ability to retain content material, amount of higher-order thinking, quality of work, ability to work independently, ability to work in groups, interaction with teachers, interaction with other students, students’ computer literacy, quality of what students learn, quantity of what students learn, personalized learning opportunities, and rigor of the curriculum.

This index is computed as the number of outcomes (as listed above) over the total number of valid responses. The higher the value, the more teachers believed that the Tablet PC improves learning for high-, low-achieving, or traditional students.

Independent Variables

Prior IT proficiency is 5-point survey item, ranging from very poor to excellent, which asked “How do you rate your proficiency in IT/computer skills before the use of Tablet PC?”

Amount of home use is a 4-point survey item, ranging from none to greater than 4 hours, which asked “How many hours do you use your Tablet PC at home per day?” Amount of school use is a similar 4-point item which asked “How many hours do you use your Tablet PC in school per day?” Technology-savvy home is an index that added the number of technologies the teachers had at home, such as a desktop or laptop computer, mobile phone, videogames, MP3 player, and a high-speed Internet connection. These variables, along with years of teaching, gender, and length of the Tablet PC program implementation, give us background on the teachers.

We also measured how much teachers used the Tablet PC to support their teaching practices and what changes they perceived in the classroom as a result of the Tablet PC. Amount of use to support teaching practices (alpha = .92) is a 12-item variable of the following activities:

- searching for information
- conducting research for lesson plans or curriculum design
- e-mailing
- developing instructional materials
- developing student assessments
- producing homework assignments
- organizing information
- creating presentations
- collaborating with colleagues
- grading student work
- giving students feedback on their work
- organizing classroom activities in accordance with a lesson plan

These survey items use a 4-point scale.

---

Table 6: Survey Items Constituting the Student Learning Improvement Variable

<table>
<thead>
<tr>
<th>Survey Items Constituting the Student Learning Improvement Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>- I like my students to learn on a Tablet PC.</td>
</tr>
<tr>
<td>- I have more access to educational resources.</td>
</tr>
<tr>
<td>- My students find Tablet PCs useful in visualizing concepts.</td>
</tr>
<tr>
<td>- Tablet PCs encourage a different form of communication between me and my students.</td>
</tr>
<tr>
<td>- I like to discuss schoolwork with my students using Tablet PC.</td>
</tr>
<tr>
<td>- Tablet PCs help the students’ development of higher order thinking skills.</td>
</tr>
<tr>
<td>- Tablet PCs improved the students’ achievement in my class.</td>
</tr>
<tr>
<td>- Every student should own one Tablet PC so that we can continue schoolwork outside classroom hours.</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>
ranging from None to More than 4 hours. **Classroom practices to improve learning** is an index of the change in amount (less often, about the same, and more often) of positive classroom practices by students: selecting their own topics for assignments, exploring a subject area on their own, researching beyond their textbooks, using online materials for learning, working in groups, writing more about a subject area, taking quizzes and tests, interacting with teachers, teaching other students, and presenting their work in class.

The survey as designed by IDA contained questions about teachers’ experience with 12 applications that were developed for use on the Tablet PC in educational settings. Not all teachers had experience with all of these applications, but IDA was interested in learning as much as it could about the applications. Rather than analyzing the answers to each pair of questions about an application (subject in which the application was used and experience with the application), we took the count of applications used in each subject to be a measure of total exposure to Tablet PC applications. The index counted each time a teacher said an application was used in a subject area. **Total exposure to Tablet PC applications** counted use of these applications: Mind Book, Fun with Construction, Virtual Classroom, EduLearn (or MLG for the CGS teachers), EduWare, SketchPad, Learning of Mathematics with Tablet, Science Practical Assessment, Training in Chinese Character Writing, ChemistPad, Input of Mathematics Formulas, and Assessment of Chinese Vocabulary. For each application, teachers checked positive or negative statements about it, such as “This application is easy to use” or “I am often frustrated using this application.” Responses to the three positive statements (out of six total) were counted to make up the **Positive experiences using the applications** variable.

The overall conceptual framework for the analysis, showing the possible connections between teacher control variables, Tablet PC experience, and outcomes, is shown in Figure 2.

**Analysis**

Analysis of the teacher survey involved four main steps: (1) computing descriptive statistics on all survey items, (2) conducting a confirmatory variable analysis, (3) analyzing the reliability and validity of the variables and indices, and (4) running a series of regressions in a hierarchical manner. The first step, which involved computing aggregate responses for each survey item, was used to both report detailed results and inform the second-stage analysis. During this step, we also conducted quality control of the data, verifying missing information and producing a report of summary results.

The second step, creating variables and indices from the individual survey responses, was an iterative process. We discussed how a series of survey items might fit together, using information from the descriptive results and past literature. Once survey items were grouped together manually, a reliability analysis was conducted. From these results, some variables that had low reliability were reanalyzed so that all variables had high reliability (i.e., an alpha value greater than .70).

The third step was running various diagnostic analyses, such as probability plots, histograms, and correlations on each of the variables and indices. These statistics insure that the variables used in the regression analyses are independent and normally distributed.

The fourth step was running a series of hierarchical linear regressions. Hierarchical linear regression is a theoretically driven stepwise model, in which a group of variables is entered in
the regression model first, and then a second group is entered. The final model is a simultaneous regression model. For each model, we see the $R^2$ change, the change in the point estimation, and significance level. Unlike forward or backward stepwise regression, which relies solely on computation, the hierarchical method relies also on theory for exploratory analysis. We first ran a series of hierarchical regressions on the whole sample, combining teachers from CHS and CGS. In most of the models, there were no significant differences between teachers in CHS and CGS. Hence, in contrast to the student analyses, we ran the teacher sample as a whole with school membership as an additional variable.

**Results**

Teachers’ perceptions about how helpful the Tablet PC was for improving the learning of students differed depending on whether the students were considered traditional, low-achieving, or high-achieving. For high-achieving students, there were no significant differences between student learning improvements and any of these: more positive classroom practices, positive experiences that teachers had with Tablet PC applications, teachers’ exposure to Tablet PC applications, and amount of use of Tablet PC for teaching practices (see Table 8). This finding suggests that for high-achieving students, teachers perceive learning to occur regardless of the presence of the Tablet PC. For both traditional and low-achieving students, teachers felt these students improved their learning quantity and quality if positive classroom practices increased, and if teachers had more positive experiences with the Tablet PC applications. Teachers’ total exposure to Tablet PC applications was not a significant predictor of teacher perceptions of student learning (see Table 8).

An interesting note for low-achieving students is the difference by school. CHS teachers felt that the Tablet PC had a negative effect on low-achieving students, as compared with CGS teachers (Table 8, see row labeled “Catholic High School”). Teacher perceptions of improvement for low-achieving students are, on average, .419 higher for CGS than for CHS. This result can be due to differences in how long the teachers have been using the Tablet PC in their teaching and how much control they have in their classroom with a potentially disruptive tool. Especially for lower-achieving students, getting acclimated to learn from the Tablet PC may be more difficult than for traditional or high-achieving students.

Positive teacher attitudes toward the Tablet PC were related to IT proficiency before Tablet PC use, positive experiences with Tablet PC applications, and classroom practices with the Tablet PC (see Table 7). For teacher perceptions of student learning and learning behaviors (such as discussing schoolwork using the Tablet PC), there was an interesting finding based on teacher experience. The more positive experiences teachers had with Tablet PC applications and the more they increased positive classroom practices, the more teachers felt that it helped students learn (see Table 7).

Taken as a whole, the major themes across teacher perceptions of pedagogy and learning are the importance of having positive experiences with the applications and spending more time integrating the Tablet PC into classroom practices. CHS teachers felt that the Tablet PC may not be beneficial for low-achieving students, as compared with CGS teachers.
Figure 2: Conceptual Framework for the Analysis of Teacher Responses

Teacher Control Variables

- Amount of home/school use
- School
- Technology-savvy home
- Prior IT proficiency
- Gender
- Years teaching

Overall Usage of Tablet PCs

Teacher Background

Tablet PC Experience

- Classroom practices to improve learning
- Amount of use to support teaching practices
- Total exposure to Tablet PC applications
- Positive experiences using the applications

Types of Usage

Experience with Tablet Applications

Outcomes

- Improved learning (high)
- Improved learning (low)
- Improved learning (traditional)
- Attitudes toward Tablet PC use
- Student learning improvements
Table 7: Regression Results for Attitudes toward Tablet PC Use and Student Learning Improvements

<table>
<thead>
<tr>
<th></th>
<th>Attitudes toward Tablet PC use</th>
<th></th>
<th>Student learning improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1 (β, s.e.)</td>
<td>Model 2 (β, s.e.)</td>
<td>Model 1 (β, s.e.)</td>
</tr>
<tr>
<td>Intercepts</td>
<td>-5.772** (1.988)</td>
<td>-4.256 (1.549)</td>
<td>-0.934 (2.162)</td>
</tr>
<tr>
<td>Female</td>
<td>-0.267 (0.410)</td>
<td>-0.206 (0.323)</td>
<td>-0.455 (0.489)</td>
</tr>
<tr>
<td>Catholic High School</td>
<td>-0.174 (0.458)</td>
<td>0.124 (0.340)</td>
<td>-0.781 (0.488)</td>
</tr>
<tr>
<td>Number of years teaching experience</td>
<td>-0.111 (0.121)</td>
<td>-0.177 (0.091)</td>
<td>-0.086 (0.143)</td>
</tr>
<tr>
<td>IT proficiency before Tablet PC</td>
<td>0.976*** (0.249)</td>
<td>0.813*** (0.177)</td>
<td>0.345 (0.297)</td>
</tr>
<tr>
<td>Tablet PC use for teaching</td>
<td>-0.007 (0.228)</td>
<td>-0.193 (0.170)</td>
<td>-0.238 (0.270)</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.328 (0.186)</td>
<td>0.120 (0.152)</td>
<td>0.436 (0.204)</td>
</tr>
<tr>
<td>Amount of Tablet PC use at school</td>
<td>0.548 (0.270)</td>
<td>0.284 (0.215)</td>
<td>0.143 (0.317)</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.191 (0.122)</td>
<td>0.069 (0.094)</td>
<td>0.138 (0.132)</td>
</tr>
<tr>
<td>Total exposure to Tablet PC</td>
<td></td>
<td>-0.155 (0.120)</td>
<td>0.095 (0.083)</td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.514** (0.179)</td>
<td>0.405** (0.135)</td>
<td>0.405** (0.135)</td>
</tr>
<tr>
<td>Classroom practices using Tablet PC</td>
<td>0.187*** (0.050)</td>
<td></td>
<td>0.193*** (0.038)</td>
</tr>
<tr>
<td>Frequency of Tablet PC use to support learning and teaching</td>
<td>0.039 (0.142)</td>
<td>0.079 (0.129)</td>
<td>0.079 (0.129)</td>
</tr>
<tr>
<td>R²</td>
<td>0.642*** (0.860***</td>
<td>0.389 (0.864***</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

The regression models are based on 42 teachers.

*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.

s.e. = standard error.

This row represents coding for gender. This cell can be read as stating that female teachers have perceptions which are, on average, .206 lower than comparable male teachers.

This row represents coding for school. This cell can be read as stating that Model 2 shows that CHS teachers have perceptions of student learning improvements that are .288 lower than comparable CGS teachers.
### Table 8: Regression Results for Perceptions of Learning for Students of Different Prior Achievement Levels

<table>
<thead>
<tr>
<th></th>
<th>Perceptions of improved learning for high-achieving students</th>
<th>Perceptions of improved learning for low-achieving students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td></td>
<td>( \beta )</td>
<td>s.e.</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.813</td>
<td>0.887</td>
</tr>
<tr>
<td>Female</td>
<td>-0.379</td>
<td>0.201</td>
</tr>
<tr>
<td>Catholic High School</td>
<td>-0.074</td>
<td>0.200</td>
</tr>
<tr>
<td>Number of years teaching</td>
<td>0.056</td>
<td>0.059</td>
</tr>
<tr>
<td>IT proficiency before Tablet PC</td>
<td>0.101</td>
<td>0.122</td>
</tr>
<tr>
<td>Tablet PC use for teaching</td>
<td>0.054</td>
<td>0.111</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.132</td>
<td>0.084</td>
</tr>
<tr>
<td>Amount of Tablet PC use at school</td>
<td>0.247</td>
<td>0.130</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.075</td>
<td>0.054</td>
</tr>
<tr>
<td>Total exposure to Tablet PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classroom practices using Tablet PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of Tablet PC use to support learning and teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R(^2)</td>
<td>0.323</td>
<td>0.539</td>
</tr>
</tbody>
</table>

**Notes:**
- The regression models are based on 42 teachers.
- *** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.
- s.e. = standard error.
<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th></th>
<th>Model 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>s.e.</td>
<td>β</td>
<td>s.e.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.091</td>
<td>0.706</td>
<td>2.143***</td>
<td>0.440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>-0.401</td>
<td>0.160</td>
<td>-0.454***</td>
<td>0.098</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catholic High School</td>
<td>-0.220</td>
<td>0.159</td>
<td>-0.151</td>
<td>0.092</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of years teaching experience</td>
<td>0.030</td>
<td>0.047</td>
<td>0.024</td>
<td>0.027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT proficiency before Tablet PC</td>
<td>0.110</td>
<td>0.097</td>
<td>0.049</td>
<td>0.053</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tablet PC use for teaching</td>
<td>-0.031</td>
<td>0.088</td>
<td>-0.084</td>
<td>0.049</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.170</td>
<td>0.067</td>
<td>0.065</td>
<td>0.044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of Tablet PC use at school</td>
<td>0.268</td>
<td>0.104</td>
<td>0.063</td>
<td>0.064</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.077</td>
<td>0.043</td>
<td>0.019</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total exposure to Tablet PC applications</td>
<td>0.052</td>
<td>0.028</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.176***</td>
<td>0.045</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classroom practices using Tablet PC</td>
<td>0.072***</td>
<td>0.013</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of Tablet PC use to support learning and teaching</td>
<td>0.103</td>
<td>0.043</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.496</td>
<td></td>
<td>0.882***</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
The regression models are based on 42 teachers.
*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.
s.e. = standard error.
**Student Survey Quantitative Analysis and Results**

**Student Sample**
Students from Catholic High School and Crescent Girls’ School participated in the survey in May 2005. There were 293 students from CHS who participated and 344 students from CGS: the ages of both groups ranged from 12 to 16 years old.

**Procedures**
All surveys were taken online (on the Tablet PCs) during one class period in which all students came to an assembly hall. Both schools were given the same instructions about completing the survey with the exception of the question set related to applications used on the Tablet PC. For this question, students at CHS were instructed to answer questions relating to only five out of the set of nine applications and for all others to select “Not Applicable.” For CGS, students were told to answer all questions, but for the application named as “EduLearn” the students were told to view it as asking about “MLG.” Because we treated these responses in an aggregate fashion in the analysis (see the following section, under Independent Measures), any small variability or errors introduced by this modification of the survey instructions would not affect the results.

The survey at CGS was administered and overseen by a researcher from SRI International, a staff member from Singapore’s BackPack.NET Centre, a member of IDA of Singapore, and a researcher from Singapore’s XpressWorks. At CHS, the survey was administered and overseen by a researcher from SRI, the technology director of CHS, a member of IDA, and a researcher from XpressWorks.

Before full administration of the survey, a pilot of the survey was conducted to ensure that it was age, language, and context appropriate. Wording changes were made to the survey after the pilot, and English was not a barrier to survey completion.

**Measures**

**Dependent Variables**

**Helps in learning in subjects** is an index where students selected subjects in which the Tablet PC was helpful to their learning. The subjects were English Language, Malay Language, Chinese Language, Literature, Geography, History, Aesthetics (PE & CCA), Mathematics, Science, Home Economics, Arts and Crafts, Design and Technology, and Civics and Moral Education. This variable ranged from 0 (helpful in no subjects) to 13 (helpful in all subjects).

**Learning behaviors** is a four-item factor that assesses how the Tablet PC helped students to learn. Students answered on a 5-point rating scale of *strongly disagree* to *strongly agree* these questions:

- I can learn a lot using Tablet PCs.
- Tablet PCs improve the quality of my schoolwork.
- Tablet PCs allow me to learn independently.
- Learning with a Tablet PC is helping me to prepare for the future.
This continuous variable was standardized (mean = 0, standard deviation = 1), and the higher the number, the more students reported learning more through the Tablet PC.

**Attitudes toward using the Tablet PC** (alpha = .809) is a nine-item variable that assesses students’ positive attitudes toward the Tablet PC. On a 5-point scale of strongly disagree to strongly agree. The survey items included in this variable are shown in Table 9.

**Time and efficiency** is a five-item factor that assesses how students are more organized and efficient in doing their work. On a 5-point scale of strongly disagree to strongly agree, items included “Tablet PCs help me save time” and “Tablet PCs help me organize my work.”

**Independent Variables**

**Prior IT proficiency** is 5-point survey item ranging from very poor to excellent that asked “How would you rate your proficiency in IT/computer skills before the use of Tablet PC?” **Amount of home use** is a 4-point survey item ranging from none to greater than four hours, which asked “How many hours do you use your Tablet PC at home on a daily basis?” **Amount of school use** is a similar 4-point survey item, which asked “How many hours do you use your Tablet PC in school on a daily basis?” **Technology-savvy home** is an index that added the number of technologies the students had at home, such as a desktop or laptop computer, mobile phone, videogames, MP3 player, and high-speed Internet, to serve as a proxy for technological sophistication in the home.

**Frequency of use** (alpha = .75) to support entertainment, communication, and collaboration is a combination of the following activities: e-mailing, working in groups, chat/instant messaging, watching movies, playing games and listening to music. **Frequency of use** (alpha = .897) to support learning is a factor of the following activities: searching for information; typing and editing reports; taking notes; organizing information; preparing presentations; learning online; creating graphics, art, or drawings; creating spreadsheets or charts; accessing school information; reading; and highlighting. These survey items use a 5-point scale ranging from never used the Tablet PC to more than four hours Tablet PC use.

**Total exposure to Tablet PC applications** is an index of the number of applications students used in various subjects. Applications included Mind Book, Fun with Construction, Virtual Classroom, EduLearn (or MLG for the CGS students), EduWare, SketchPad, Learning of Mathematics with Tablet, Science Practical Assessment, Training in Chinese Character Writing, ChemistPad, Input of Mathematics Formulas, and Assessment of Chinese Vocabulary. For each application they reported using, students checked positive or negative statements about it, such as “This application is easy to use” or “I am often frustrated using this application.” Responses to the

---

9 Alpha is a measure of internal reliability—it measures how well the items can combine to form a variable.
three positive statements (out of six total) were counted to make up the **Positive experiences using the applications** variable.

**Convenience** is an index of the number of times students checked the following statements: use the Tablet PC anywhere, teacher doesn’t control when to use it, can load any applications, convenient to use anywhere, enjoy reading off of the Tablet PC, way of taking notes has changed, and battery time does not get in the way. **Classroom practices to improve learning** is an index of the change in amount *(less often, about the same, and more often)* of positive classroom practices by students: selecting their own topics for assignments, exploring a subject area on their own, researching beyond their textbooks, interacting with teachers, teaching other students, and presenting their work in class.

The overall conceptual framework for the analysis, showing the possible connections between student control variables, Tablet PC experiences, and outcomes, is shown in Figure 3.

**Analysis**

Analysis of the student survey involved four main steps: (1) computing descriptive statistics on all survey items; (2) conducting a confirmatory variable analysis; (3) analyzing the reliability and validity of the factors and indices; and (4) running a series of regressions in a hierarchical manner. The first step, which involved computing aggregate responses for each survey item, was used to both report detailed results and inform the second stage analysis. During this step, we also conducted quality control of the data, verifying missing information, and producing a report of initial results. These results are presented in Appendices D and F.

The second step, creating variables and indices from the individual survey responses, was an iterative process. We discussed how a series of survey items might fit together, using information from the descriptive results and past literature. Once survey items were grouped together manually, a reliability analysis was conducted. From these results, some variables that had low reliability were reanalyzed so that all variables had high reliability (alpha greater than .70).

The third step was running various diagnostic analyses, such as probability plots, histograms, and correlations on each of the factors and indices. These tests insure that the variables used in the regression analyses will be independent and normally distributed.

The fourth step was running a series of hierarchical linear regressions. Hierarchical linear regression is a theoretically driven stepwise model, in which a group of variables is entered in the regression model first, and then a second group is entered. The final model ends with a simultaneous regression model. For each model, we see the $R^2$ change, the change in the point estimation, and significance level. Unlike forward or backward stepwise regression, which relies solely on computation, the hierarchical method relies on theory for exploratory analysis. We first ran a series of hierarchical regressions on the whole sample (which combined students from CHS and CGS). Because of differences between the schools, we ran another set of hierarchical regressions by school.

**Results**

There were significant differences between student perceptions of Tablet PC use at CHS versus CGS. Interestingly, whereas perceptions of how the Tablet PC helps in learning in subjects,
improvements in learning behaviors, and efficiency in work were significantly different, attitudes toward using the Tablet PC were similar.

For how the Tablet PC helps in learning in subjects, positive experience with the Tablet PC applications was a positive significant variable for CHS students. For CGS students, an increase in positive classroom practices, frequency of using the Tablet PC for learning support practices, and total exposure to applications were significant predictors (see Table 10). For CHS students, given that they had used the Tablet PC for only 5 months, applications may be most salient in their experience. Before they can learn in various subjects, students need to feel familiar and comfortable with the applications used in their classrooms. Hence, for CHS students who are still novice users, applications may be an important element to learning. For CGS students, a different set of experiences are more important to learning. Specifically, the more they use the Tablet PC (through frequency of use and total exposure to different applications), the more these students feel they are learning in various subjects. Hence, for experienced users, frequency of use is an important element to learning.

For learning behaviors, convenience and frequency of using the Tablet PC for learning support practices were positive predictors for CHS. For CGS students, convenience, an increase in positive classroom practices, frequency of use for learning support practices, and positive experiences with the Tablet PC applications were positive significant factors (see Table 11). Across the two groups, convenience was an important factor in how students used the Tablet PC and learned from it. In addition to convenience, the more students from both schools used the Tablet PC for learning activities, the more they reported that they learned. With CGS students who had used the Tablet PC longer than the CHS students, another factor important in their learning was their positive experiences with the applications they used in school. Not only is convenience of the hardware important, but applications play a critical role in learning for more experienced users.

For attitudes in using the Tablet PC, students in both schools had similar results, where convenience, positive classroom practices, and positive experiences with the applications were significant positive predictors. Interestingly, there were no differences across the two schools on attitudes (Table 12). Regardless of how long students had been using the Tablet PC, students on average had positive attitudes toward the Tablet PC, where convenience and positive experiences were critical to positive attitudes. For CGS students, convenience and frequency of use for learning activities were significant positive factors (Table 13).

Taken as a whole, convenience is a major theme across the two groups of students. Convenience of the Tablet PC was related to learning, attitudes, and efficiency. Another major theme is the frequency of use for learning activities. The more students used the Tablet PC for learning activities, the more they reported it helped them learn in various subjects and made their work more efficient.
Figure 3: Conceptual Framework for the Analysis of Student Responses

**Student Control Variables**

- Overall Usage of Tablet PCs
  - Amount of Tablet PC use in school
  - Amount of Tablet PC use at home
  - Technology-savvy home
  - Prior IT proficiency

**Student Background**

**Types of Usage**

- Experience with Tablet Applications

**Benefits of Tablet PCs**

- How convenient is it to use?
- Increased positive classroom practices
- Skills for learning
- Entertainment/collaboration/communication frequency
- Total exposure to Tablet PC applications
- Positive experience with Tablet PC applications

**Outcomes**

- Helps in learning in subjects
- Learning behaviors
- Attitudes toward using the Tablet PC
- Time and efficiency
### Table 10: Regression Results for Variable “Helps in Learning in Subjects” for CHS and CGS Students

<table>
<thead>
<tr>
<th></th>
<th>Catholic High School</th>
<th></th>
<th>Crescent Girls’ School</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td></td>
<td>Model 1</td>
</tr>
<tr>
<td>Intercept</td>
<td>3.038</td>
<td>1.520</td>
<td>3.070</td>
<td>1.685</td>
</tr>
<tr>
<td>Amount of Tablet PC use in school</td>
<td>0.250</td>
<td>0.333</td>
<td>0.059</td>
<td>0.341</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.153</td>
<td>0.290</td>
<td>-0.100</td>
<td>0.319</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.203</td>
<td>0.141</td>
<td>0.110</td>
<td>0.140</td>
</tr>
<tr>
<td>Prior IT proficiency</td>
<td>0.271</td>
<td>0.231</td>
<td>0.230</td>
<td>0.226</td>
</tr>
<tr>
<td>Convenience</td>
<td>0.249</td>
<td>0.151</td>
<td></td>
<td>0.070</td>
</tr>
<tr>
<td>Increased positive classroom practices</td>
<td>0.060</td>
<td>0.109</td>
<td></td>
<td>0.270</td>
</tr>
<tr>
<td>Frequency of use: learning support practices</td>
<td>0.058</td>
<td>0.219</td>
<td></td>
<td>0.414</td>
</tr>
<tr>
<td>Frequency of use: entertainment, collaboration, communication</td>
<td>0.204</td>
<td>0.233</td>
<td></td>
<td>-0.110</td>
</tr>
<tr>
<td>Total exposure to Tablet PC applications</td>
<td>0.047</td>
<td>0.032</td>
<td></td>
<td>0.059</td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.861</td>
<td>0.263</td>
<td></td>
<td>0.207</td>
</tr>
<tr>
<td>R²</td>
<td>0.025</td>
<td>0.122***</td>
<td></td>
<td>0.067***</td>
</tr>
</tbody>
</table>

**Notes:**

For CHS, the regression models are based on 293 students, and for CGS, the regression models are based on 344 students.

*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.

s.e. = standard error.
### Table 11: Regression Results for “Learning Behaviors” for CHS and CGS Students

<table>
<thead>
<tr>
<th></th>
<th>Catholic High School</th>
<th></th>
<th>Crescent Girls’ School</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Intercept</td>
<td>11.907***</td>
<td>1.307</td>
<td>12.322***</td>
<td>1.329</td>
</tr>
<tr>
<td>Amount of Tablet PC use in school</td>
<td>0.361</td>
<td>0.284</td>
<td>-0.249</td>
<td>0.269</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.261</td>
<td>0.250</td>
<td>0.145</td>
<td>0.252</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.118</td>
<td>0.120</td>
<td>0.101</td>
<td>0.109</td>
</tr>
<tr>
<td>Prior IT proficiency</td>
<td>0.198</td>
<td>0.194</td>
<td>0.089</td>
<td>0.174</td>
</tr>
<tr>
<td>Convenience</td>
<td>0.708***</td>
<td>0.117</td>
<td>0.481***</td>
<td>0.112</td>
</tr>
<tr>
<td>Increased positive classroom practices</td>
<td>0.131</td>
<td>0.085</td>
<td>0.445***</td>
<td>0.086</td>
</tr>
<tr>
<td>Frequency of use: learning support practices</td>
<td>0.709***</td>
<td>0.172</td>
<td>0.594***</td>
<td>0.161</td>
</tr>
<tr>
<td>Frequency of use: entertainment, collaboration, communication</td>
<td>0.015</td>
<td>0.183</td>
<td>-0.037</td>
<td>0.171</td>
</tr>
<tr>
<td>Total exposure to Tablet PC applications</td>
<td>0.033</td>
<td>0.025</td>
<td>0.014</td>
<td>0.021</td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.041</td>
<td>0.207</td>
<td>0.610**</td>
<td>0.214</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.027</td>
<td>0.252***</td>
<td>0.067***</td>
<td>0.212***</td>
</tr>
</tbody>
</table>

Notes:
- For CHS, the regression models are based on 293 students.
- For CGS, the regression models are based on 344 students.

*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.

s.e. = standard error.
Table 12: Regression Results for “Attitudes toward using the TabletPC” for CHS and CGS Students

<table>
<thead>
<tr>
<th></th>
<th>Catholic High School</th>
<th></th>
<th>Crescent Girls’ School</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>s.e.</td>
<td>β</td>
<td>s.e.</td>
</tr>
<tr>
<td>Intercept</td>
<td>-2.096*** 0.501</td>
<td>-2.262*** 0.518</td>
<td>-2.178*** 0.437</td>
<td>-2.697*** 0.427</td>
</tr>
<tr>
<td>Amount of Tablet PC use in school</td>
<td>0.327** 0.109</td>
<td>0.190 0.105</td>
<td>0.277** 0.095</td>
<td>0.123 0.080</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.124 0.096</td>
<td>0.039 0.100</td>
<td>0.356*** 0.075</td>
<td>0.246*** 0.070</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.015 0.046</td>
<td>0.000 0.043</td>
<td>-0.005 0.063</td>
<td>-0.043 0.053</td>
</tr>
<tr>
<td>Prior IT proficiency</td>
<td>0.154 0.075</td>
<td>0.137 0.068</td>
<td>0.069 0.086</td>
<td>0.033 0.071</td>
</tr>
<tr>
<td>Convenience</td>
<td>0.206*** 0.046</td>
<td>0.069 0.086</td>
<td>0.187*** 0.042</td>
<td></td>
</tr>
<tr>
<td>Increased positive classroom practices</td>
<td>0.092** 0.033</td>
<td></td>
<td>0.165*** 0.032</td>
<td></td>
</tr>
<tr>
<td>Frequency of use: learning support practices</td>
<td>0.100 0.068</td>
<td></td>
<td>0.074 0.061</td>
<td></td>
</tr>
<tr>
<td>Frequency of use: entertainment, collaboration, communication</td>
<td>0.055 0.072</td>
<td></td>
<td>0.047 0.064</td>
<td></td>
</tr>
<tr>
<td>Total exposure to Tablet PC applications</td>
<td>-0.006 0.010</td>
<td></td>
<td>0.009 0.008</td>
<td></td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.227** 0.082</td>
<td></td>
<td>0.357*** 0.082</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.073***</td>
<td>0.264***</td>
<td>0.129***</td>
<td>0.421***</td>
</tr>
</tbody>
</table>

Notes:
For CHS, the regression models are based on 293 students and for CHS, the regression models are based on 344 students.
*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.
s.e. = standard error.
Table 13: Regression Results for “Time and Efficiency” for CHS and CGS Students

<table>
<thead>
<tr>
<th></th>
<th>Catholic High School</th>
<th></th>
<th>Crescent Girls’ School</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td></td>
<td>β        s.e.</td>
<td>β        s.e.</td>
<td>β         s.e.</td>
<td>β         s.e.</td>
</tr>
<tr>
<td>Intercept</td>
<td>15.466*** 1.282</td>
<td>17.155*** 1.407</td>
<td>15.374*** 1.008</td>
<td>15.280*** 1.114</td>
</tr>
<tr>
<td>Amount of Tablet PC use in school</td>
<td>0.168 0.279</td>
<td>-0.155 0.285</td>
<td>0.027 0.223</td>
<td>-0.255 0.214</td>
</tr>
<tr>
<td>Amount of Tablet PC use at home</td>
<td>0.469 0.245</td>
<td>0.171 0.267</td>
<td>0.322 0.178</td>
<td>0.113 0.191</td>
</tr>
<tr>
<td>Technology-savvy home</td>
<td>0.083 0.117</td>
<td>-0.004 0.115</td>
<td>-0.050 0.148</td>
<td>-0.091 0.142</td>
</tr>
<tr>
<td>Prior IT proficiency</td>
<td>-0.364 0.191</td>
<td>-0.436 0.184</td>
<td>-0.092 0.200</td>
<td>-0.150 0.189</td>
</tr>
<tr>
<td>Convenience</td>
<td>0.239 0.124</td>
<td>0.384*** 0.113</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased positive classroom practices</td>
<td>-0.075 0.090</td>
<td></td>
<td>0.099 0.086</td>
<td></td>
</tr>
<tr>
<td>Frequency of use: learning support practices</td>
<td>0.392 0.183</td>
<td></td>
<td>0.450** 0.163</td>
<td></td>
</tr>
<tr>
<td>Frequency of use: entertainment, collaboration, communication</td>
<td>0.325 0.194</td>
<td></td>
<td>-0.051 0.173</td>
<td></td>
</tr>
<tr>
<td>Total exposure to Tablet PC applications</td>
<td>0.049 0.027</td>
<td></td>
<td>0.017 0.021</td>
<td></td>
</tr>
<tr>
<td>Positive experience with Tablet PC applications</td>
<td>0.364 0.219</td>
<td></td>
<td>0.251 0.216</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.042   0.148***</td>
<td>0.012    0.144***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
For CHS, the regression models are based on 293 students and for CGS, the regression models are based on 344 students.

*** = estimated coefficient statistically significant at < .01 level; ** = estimated coefficient statistically significant at < .05 level.
s.e. = standard error.
Student Survey Open-Ended Questions

Coding Open-Ended Survey Items

The preceding section presented results regarding demographics, technology use, and perceptions of Tablet PC use in students’ learning and opinions toward Tablet PC applications. In addition to these quantitative responses, students completed open-ended questions about the different ways they used the Tablet PC and what they liked and disliked about it. This section provides summary results on these open-ended questions.

All open-ended questions were coded into specific categories, such as Internet research, homework, and art. The process of forming the coding categories had multiple steps. The first step was to create the coding categories from a sample of the data. Ten student survey responses from each school were randomly selected. Two coders reviewed the responses separately to formulate the coding categories. The coders discussed their coding and finalized the coding categories. After this discussion, in the second step, a new coder was trained on how to code the open-ended responses with the coding categories, without seeing the results of the first coding. After the training, the new coder coded, separately, the same 10 cases that were used to create the codes, obtaining an intercoder reliability of 91% for the Crescent Girls’ School students and 94% for the Catholic High School students. This intercoder reliability was calculated by dividing the total items agreed between the two coders in all the open-ended questions considered by the total possible number of agreements.

The third step of the process involved selecting a random sample of 50 cases per school. From within those cases, 20 cases were selected randomly for each school, so that the two coders could separately code and again test their intercoder reliability. Using this random sample of 20 cases per school, the intercoder reliability was 96% for the CGS students and 93% for the CHS students. Coder drift was checked by selecting a random case at the end of the coding process and having the reliability coder code the case and compare his results with the primary coder results. The intercoder reliability for the coder drift remained high at 96% for CGS and 82% for CHS. Once high intercoder reliability was established in step three, step four was to complete the coding by the primary coder following the coding categories. At this time, four new categories were devised based on this new data and checked between the two coders for agreement. The final coding categories are listed in Appendix B.

The coding was then performed on all of the student responses. The student sample consisted of 293 students who took the survey from CHS and 344 who took the survey from CGS. Because the survey responses for both schools were similar, they were combined.
Results from Open-Ended Questions

Overall, students were very forthcoming in providing information on how they plan to use the Tablet PC in the future and about what they liked and disliked about the use of the Tablet PC, as well as suggestions for improving the Tablet PC. Even though CHS students have been using the Tablet PC for 5 months, while the CGS students had been using it for 12 months, the responses were very similar across schools.

On average, students across the two schools used the Tablet PC for:

- Internet research
- Homework and project work
- Designing Web sites
- Art
- Making presentations

Students from both schools plan to use the Tablet PC for activities related to the use of the Internet (Table 14). The three categories that obtained the highest percentages of answers involve the use of the Internet; most of the students who plan to use their Tablet PC to do homework and projects also mentioned doing these activities with the help of the Internet.

Table 14: Different Ways in Which Students Plan to Use the Tablet PC in the Future

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet Research</td>
<td>288</td>
<td>46.5</td>
</tr>
<tr>
<td>Design Web site</td>
<td>248</td>
<td>40.0</td>
</tr>
<tr>
<td>Homework/Project</td>
<td>236</td>
<td>38.1</td>
</tr>
<tr>
<td>Presentations</td>
<td>212</td>
<td>34.2</td>
</tr>
<tr>
<td>Art</td>
<td>207</td>
<td>33.4</td>
</tr>
<tr>
<td>Note Taking</td>
<td>154</td>
<td>24.8</td>
</tr>
<tr>
<td>Communication/Relationship</td>
<td>107</td>
<td>17.3</td>
</tr>
<tr>
<td>Games</td>
<td>76</td>
<td>12.3</td>
</tr>
<tr>
<td>Writing</td>
<td>69</td>
<td>11.1</td>
</tr>
<tr>
<td>Study</td>
<td>62</td>
<td>10.0</td>
</tr>
<tr>
<td>IT Skills</td>
<td>56</td>
<td>9.0</td>
</tr>
<tr>
<td>Collaboration</td>
<td>55</td>
<td>8.9</td>
</tr>
<tr>
<td>Organize</td>
<td>53</td>
<td>8.5</td>
</tr>
<tr>
<td>Listen to Music</td>
<td>52</td>
<td>8.4</td>
</tr>
<tr>
<td>Read</td>
<td>25</td>
<td>4.0</td>
</tr>
<tr>
<td>Watch Movies</td>
<td>15</td>
<td>2.4</td>
</tr>
</tbody>
</table>

It is interesting that a large percentage of the students plan to use the Tablet PC to do schoolwork, such as preparing presentations and note taking. Students responded with other categories like playing games, communicating with others, and listening to music, with lower percentages than school-related activities, which suggests that the main future uses that students see in the Tablet PC are connected to the improvement of their education.
However, it is also interesting that the students plan to use the Tablet PC in a multidimensional way, and not only for school. For example, almost 34% of the students plan to use the Tablet PC for arts, doing activities such as creating music video clips, creating movies, editing pictures, drawing, and making animations using Flash. More than 12% plan to use the Tablet PC to play games, and almost 9% of the students plan to download and listen to music on their computers.

Students were consistent in reporting what they liked about the Tablet PC (as shown in Table 15). The top three benefits of the Tablet PC were:

- Convenience
- Ease of use
- Internet research.

In general, students had a positive opinion about the Tablet PC. When asked about what they liked about using the Tablet PC, 34% of them mentioned that the computers are very convenient and portable. Some of them went further and suggested that they should have all books in the computer and get rid of the actual textbooks. More than 50% of the students think that it is positive to have Tablet PCs either because they are convenient, portable, efficient, or easy to use.

Table 15: What Students Like about Using the Tablet PC

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable/Convenient</td>
<td>214</td>
</tr>
<tr>
<td>Fast Work/Efficiency/Ease of Use</td>
<td>161</td>
</tr>
<tr>
<td>Research on Internet</td>
<td>129</td>
</tr>
<tr>
<td>Notes</td>
<td>83</td>
</tr>
<tr>
<td>Improved Learning</td>
<td>74</td>
</tr>
<tr>
<td>Internet Access/Wireless</td>
<td>53</td>
</tr>
<tr>
<td>Homework/Presentations</td>
<td>52</td>
</tr>
<tr>
<td>Entertainment</td>
<td>34</td>
</tr>
<tr>
<td>Communication/Relationship</td>
<td>17</td>
</tr>
<tr>
<td>IT Skills</td>
<td>12</td>
</tr>
</tbody>
</table>

Again, we see that students like the fact that the Tablet PCs are helping them for schoolwork, and 12% are happy that these computers are helping them to improve their learning at school.

Even though we did not ask it directly, the results above suggest that students actually prefer having the Tablet PCs to not having them. As we will explain later, this does not mean that students are completely satisfied with the use of this technology in their classrooms.

Students were also consistent in reporting what they didn’t like about the Tablet PC (Table 16). The top five dislikes were:

- Battery life
- Weight
- Technical problems (e.g. freezing or shutting down)
- Physical discomfort
- Slow

**Table 16: What Students Dislike about Using the Tablet PC.**

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Life</td>
<td>270</td>
<td>43.7</td>
</tr>
<tr>
<td>Weight</td>
<td>112</td>
<td>18.1</td>
</tr>
<tr>
<td>Freezes/Does Not Work/</td>
<td>91</td>
<td>14.7</td>
</tr>
<tr>
<td>Tech Issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Discomfort</td>
<td>76</td>
<td>12.3</td>
</tr>
<tr>
<td>Slow</td>
<td>74</td>
<td>12.0</td>
</tr>
<tr>
<td>Design/Cleanliness/Durability</td>
<td>65</td>
<td>10.5</td>
</tr>
<tr>
<td>Distracting</td>
<td>51</td>
<td>8.3</td>
</tr>
<tr>
<td>Lack of Applications/</td>
<td>49</td>
<td>7.9</td>
</tr>
<tr>
<td>Features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless Coverage</td>
<td>30</td>
<td>4.9</td>
</tr>
<tr>
<td>Administration</td>
<td>26</td>
<td>4.2</td>
</tr>
<tr>
<td>Expensive/Theft Threat</td>
<td>23</td>
<td>3.7</td>
</tr>
<tr>
<td>Inefficient</td>
<td>21</td>
<td>3.4</td>
</tr>
<tr>
<td>Reading/Studying</td>
<td>18</td>
<td>2.9</td>
</tr>
<tr>
<td>Static Electricity</td>
<td>7</td>
<td>1.1</td>
</tr>
<tr>
<td>Notes</td>
<td>2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

It is important to note that most of the complaints about using the Tablet PCs relate to the actual technology of the computer rather than to the idea of using a Tablet PC in the classroom. Most of the students complained about the features of the computer, mainly the battery life, not having software that prevents the Tablet PC from freezing, the weight of the computer, the computer being slow, and the lack of components such as Firewire and a built-in CD drive. A low percentage of the students believe that the introduction of Tablet PCs in their classrooms is a distraction or a source of inefficiencies. This low percentage suggests that the idea of introducing Tablet PCs in classrooms is not criticized by students; it is mainly that they would prefer to have better equipment and technology.
Students had many suggestions for improving the Tablet PC (Table 17). The most common suggestions were:

- Having longer battery life and making the Tablet PC lighter.
- Providing more software for the Tablet PC.
- Having more opportunities to use the Tablet PC and improving the technical problems.

Table 17: New Ways Tablet PCs Could Be Used to Improve the Learning Experience at School

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Life</td>
<td>64</td>
</tr>
<tr>
<td>Frequency of Use</td>
<td>58</td>
</tr>
<tr>
<td>Amount of Software Available</td>
<td>54</td>
</tr>
<tr>
<td>Technical Computer Issues</td>
<td>44</td>
</tr>
<tr>
<td>Administration</td>
<td>29</td>
</tr>
<tr>
<td>Weight</td>
<td>27</td>
</tr>
<tr>
<td>Location of Internet Access Points</td>
<td>23</td>
</tr>
<tr>
<td>Work More Online</td>
<td>21</td>
</tr>
<tr>
<td>School Infrastructure</td>
<td>16</td>
</tr>
</tbody>
</table>

Again, the suggestions that students from both schools gave to improve the Tablet PC use are very positive and constructive. Students want more software that can make learning more interesting and fun, and more opportunities to use the Tablet PC during class. They would also like teachers to take more advantage of the Internet as a tool in their classes, to post things online or to interact more with the students. In concordance with their complaints, students would like to have higher-quality technology.

To conclude, the students were consistent about their likes and dislikes about the Tablet PC and were very cooperative in providing suggestions for improving the Tablet PC. These results as a whole suggest that hardware issues, such as battery life, weight, and technical problems, were the most common concern. Second, software issues, such as having a number of different software applications for the Tablet PC, were also an issue. However, these students seemed to enjoy the introduction of Tablet PCs in their classes, especially with regard to the convenience and ease of use of this technology in their school.
Tablet PC Applications and Lesson Plan Changes

Software Applications Using the Unique Form Factor of the Tablet PC

The form factor (i.e., the shape and size as they relate to the human-machine interface) of the Tablet PC lends itself to specialized applications that take advantage of pen-based computing. Bundled along with the Microsoft Tablet PC operating system (based on Windows XP) are features that let applications take advantage of inking, handwriting, and pen-based methods of interacting with objects (such as dragging, selecting, and so on). In this section, we will discuss these specialized applications, as well as describe more standard applications that take advantage of these special features.

Each school has available the Microsoft Office Pack consisting of Word, PowerPoint, Excel, and Outlook. No students or teachers mentioned using Excel, and only a few mentioned Outlook; however, PowerPoint was used frequently as teachers substituted electronic presentations for overhead transparencies. Word was also used for writing reports, but Microsoft Windows Journal (Tablet PC only, although a viewer is available for non-Tablet PC platforms), OneNote, and Sticky Notes were more often mentioned because they have special Tablet PC-related features. Windows Journal manages handwritten or text-recognized notes, providing a variety of stationery templates, printing features, and searching for text (even if handwritten). Images can be inserted, and drawings made as well. Teachers and students received training in Journal, so it was well used.

OneNote offers similar note-taking capabilities as Journal but more sophisticated management of pages, analogous to the paper world, such as binder tabs and flags on pages. Of course, being in electronic form affords additional capabilities such as searching, easy import of images from the Internet and other applications, and audio attachments. Interconnections with Outlook are also present (e.g., creating a task in OneNote that Outlook can recognize), but only a few teachers or students mentioned using Outlook. More importantly, OneNote allows, from inside the application, searches to external reference collections on the Internet, such as Encarta. Students mentioned using OneNote to organize information, but OneNote was not described as central to organizing their research efforts on the Internet.

The applications for drawing and image manipulation (including Manga art) that were used were mainly freeware or low cost, such as ArtRage (from Ambient Design Ltd.), GIMP (from the GNU software project), and ComicWorks (from Deleter). Microsoft Producer, which works with PowerPoint to support audio, video, and sharing, was also mentioned. Students also reported using Adobe Photoshop, Macromedia Flash, Alias Maya, and Producer, although these more expensive software applications were not installed on individual Tablet PCs (because of licensing issues) but instead were available in computer labs.

Companies Make Possible Adoption across the Curriculum

The investment made by partners of the BackPack.NET Centre should not be underestimated. According to the BackPack.NET press release archive, many companies made possible the pilot at Crescent Girls’ School:

- CET Technologies providing system integration services; Intel and Compex Systems providing the wireless infrastructure; Popular e-Learning and
publishers Marshall Cavendish, SNP Panpac and Pearson Education converted
digital textbooks and provided the textbook viewer; Heuristix Labs and
IdealSoft provided the digital inking applications; Fujitsu PC Asia Pacific and
Asia Pacific Distribution contributed tablet PCs for needy students; and
Commerce Online provided consultancy, deployment and customization to
implement the Microsoft Learning Gateway.\textsuperscript{10}

IdealSoft’s SketchPad demonstrates the novel uses to which drawing applications can be put, such
as providing background grids as squares for practicing Chinese characters and gridlines for
geometric drawing.

Heuristix Lab (a Singapore company) worked as a partner with CGS as part of what became a
productive school-industry collaboration. Heuristix Lab created three applications that are in use
in these schools: Fun with Construction, Mind Book, and Virtual Classroom. We describe each of
these in turn below.

**Fun with Construction.** Fun with Construction was used in Mathematics and Geography at both
schools. Although students reported (in the survey) having some problems and frustrations with
the software, it was at the same time seen by 32\% to 51\% of students as easy to use and by 20\% to
37\% as making learning fun. Interestingly, CGS students were more positive about this application
in spite of encountering problems with it, while CHS students were more negative. This difference
could be due to CGS teachers having participated in consulting on the features, and the view that
CGS students and teachers have of themselves as an experimental class.

As shown in Figure 4, Fun with Construction presents a grid background and tools such as
compass, protractor, ruler, and 45-45 and 60-30 triangles. Although developed for geometry
lessons, Fun with Construction was adapted for Geography classes to support map measurements
(e.g., for triangulation). Fun with Construction supports drawing and also, in an analog to
handwriting recognition, offers a shape recognition function. Offering as many functions as it
does, Fun with Construction requires hands-on training for teachers to make full use of it.

**Mind Book.** Mind Book offers functionality similar to OneNote for organizing school-specific
information. Offering a calendar, a document organizer, and a mind-mapping tool, Mind Book is
used by teachers (only at CGS) in English and Literature classes but, by students in a broader
range of subjects (including Mathematics and Science). CGS students had only positive
impressions of Mind Book and reported using the templates and pictures provided (e.g., the human
heart) for taking notes and labeling. In both OneNote and Mind Book, teachers made templates for
students to use for tests, quizzes, studying, or class work. Figure 5 shows hypothetical student
work from a teacher-produced template. In this figure, the ink text input box is also shown at the
bottom.

Virtual Classroom. The Virtual Classroom application was developed by Heuristix Lab as a system for classroom and learning management over a classroom network. While many of the participants interviewed for this study focused on Virtual Classroom’s ability to allow a teacher to view any or all student screens and to block unwanted applications such as chat and web browsing, Virtual Classroom also provides collaboration tools for file and presentation sharing, question and answer exchanges, and quick poll/response functions. Teachers who were
interviewed reported not having the class time to use the monitoring feature and, in the survey, reported having problems with the application (50% at CHS, 25% at CGS), and students reported less than 50% usage in their classes (with many less than 20%). At the same time, teachers saw potential for Virtual Classroom’s response feature as they moved to more immediate forms of assessment.

**Digital Textbooks.** Another major investment in the Tablet PC implementation in Singapore was the digitizing of secondary textbooks for Science, Geography, and Civics and Moral Education. These textbooks offer more than a digital layout of a textbook in three ways. One difference is the addition of multimedia content (such as animations and videos). Another difference is navigation features enabled by the digital form of the textbook, such as searching, flagging, bookmarking, and linked lesson sequences. A third difference is organizing and studying features: highlighting, adding notes, and linking pages to external documents. The latter feature is especially useful for linking mind-maps done in OneNote or Mind Book into a specific part of the textbook.

**School Portals.** The final notable applications for the Tablet PC were the school portals. CHS used SharePoint (a Windows server technology), and CGS used a portal for e-learning called Microsoft Learning Gateway (MLG). These portals provide information sharing among all school participants: students, teachers, administrators, and (eventually) parents. Students spoke of downloading presentations and assignments during class and of uploading their completed assignments after school. Students at CGS reported the most positive responses to MLG over any other application listed on the survey: 39% reported that it “makes learning more fun,” and 34% said that it “helps them learn more.” While not all teachers have made full use of the school portals, those interviewed described how it changed the sharing practice among teachers, and one stated that it could “revolutionize” teacher practices.

**Seeing Changes in Teaching through Lesson Plans**

In this study, we were not able to measure any pre-implementation variables. Thus, we used self-report data from interviews and survey data to discern areas where change may have occurred. However, we did receive a selection of paired teachers’ lesson plans, one in each pair reflecting a lesson plan written before the implementation of the Tablet PC program and the other written with the use of the Tablet PC in mind. This section describes the results of our comparison of these lesson plans.

We received lesson plans for Literature, Geography, Math, Science, History, and Chinese. The most obvious difference between the pre- and post-implementation lesson plans is that teachers have abandoned the use of the overhead transparency for content presentation; instead, they place their files in the shared space (MLG or SharePoint), and students download the material before class. This has the effect of allowing students to take notes on the PowerPoint presentation or text document or to highlight parts of it. This also aids students who are not in class because the portals can be accessed remotely.

Tables 18-23 illustrate the pre- and post-implementation lesson plans.
### Table 18: Pre and Post Literature Lesson Plan for the Book *Roll of Thunder, Hear My Cry*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewing areas of study.</td>
<td>Printed notes handed out during class.</td>
<td>Notes downloaded from MLG.</td>
<td>Easier to concentrate on understanding.</td>
</tr>
<tr>
<td>Highlighting key words.</td>
<td>Marker on printed notes.</td>
<td>Ink highlighter on Tablet PC.</td>
<td></td>
</tr>
<tr>
<td>Group work to brainstorm.</td>
<td>Transparency and markers.</td>
<td>Tablet PC.</td>
<td></td>
</tr>
<tr>
<td>Present results of group work.</td>
<td>Overhead projector.</td>
<td>Virtual Classroom and video projector.</td>
<td>Faster to share student work and more can be shown.</td>
</tr>
</tbody>
</table>

### Table 19: Pre and Post Lesson Plan for Geography: Land and Water Reclamation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclamation information.</td>
<td>Handout; hardcopy textbook.</td>
<td>Tablet PC; digitized textbook; Internet resources (WebQuest).</td>
<td></td>
</tr>
<tr>
<td>Group work</td>
<td>Worksheet with exercise for students to work on.</td>
<td>WebQuest.</td>
<td>Students more engaged with material.</td>
</tr>
<tr>
<td>Group work</td>
<td>Students work in pairs.</td>
<td>Students work in groups of 3-4; roles are assigned (researcher, presenter); and students share information with each other via infrared beaming.</td>
<td>No fixed answers. Independent learning and teamwork.</td>
</tr>
<tr>
<td>Present results of group work.</td>
<td>Students share aloud.</td>
<td>PowerPoint and video projector.</td>
<td>Engaging multimedia presentation.</td>
</tr>
</tbody>
</table>

### Table 20: Pre and Post Lesson Plan for Mathematics: Coordinate Geometry

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review method for solving equations.</td>
<td>Overhead transparency.</td>
<td>Tablet PC and video projector.</td>
<td>Software is more engaging. Removes time consuming but conceptually less important tasks so students can get to the challenging material.</td>
</tr>
<tr>
<td>Practice questions.</td>
<td>Hardcopy worksheets.</td>
<td>MLG or “thumb drive.”</td>
<td></td>
</tr>
<tr>
<td>Problem-solving method.</td>
<td>Graph paper.</td>
<td>Fun with Construction software.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 21: Pre and Post Lesson Plan for History: Fall of Singapore and Japanese Occupation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review techniques used in political</td>
<td>Handouts.</td>
<td>Tablet PC and video projector.</td>
<td></td>
</tr>
<tr>
<td>cartoons.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create their own political cartoons.</td>
<td>Paper, overhead</td>
<td>Soft-copy documents downloaded from MLG.</td>
<td>Easier for teacher to reuse</td>
</tr>
<tr>
<td></td>
<td>transparencies.</td>
<td></td>
<td>lessons.</td>
</tr>
<tr>
<td>Present group work.</td>
<td>Overhead projector and</td>
<td>Tablet PC and video projector.</td>
<td>Easier for students to share.</td>
</tr>
<tr>
<td></td>
<td>transparencies.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 22: Pre and Post Lesson Plans for Science: Atoms, Molecules, and Ions

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of previous lesson.</td>
<td>Overhead projector and</td>
<td>Tablet PC, Virtual Classroom, and an Internet Web</td>
<td>Teacher has access to resources</td>
</tr>
<tr>
<td></td>
<td>transparencies.</td>
<td>page.</td>
<td>beyond the classroom and textbook.</td>
</tr>
<tr>
<td>Lesson on electron arrangement.</td>
<td>Overhead projector and</td>
<td>Tablet PC, video projector, and an Internet Web page.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>transparencies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students present answers from work on</td>
<td>Student writes on</td>
<td>Teacher selects student work to present via Virtual</td>
<td>More student participation.</td>
</tr>
<tr>
<td>their own.</td>
<td>whiteboard.</td>
<td>Classroom.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice for Reinforcement.</td>
<td>Students complete</td>
<td>Students use Web page for practice.</td>
<td>Students can continue practice</td>
</tr>
<tr>
<td></td>
<td>worksheet.</td>
<td></td>
<td>at home.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 23: Pre and Post Lesson Plans for Chinese Language: Descriptive Writing

<table>
<thead>
<tr>
<th>Activity</th>
<th>Pre-Tablet PC</th>
<th>Post-Tablet PC</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show geographic location about which</td>
<td>Overhead projector and</td>
<td>Tablet PC and PowerPoint.</td>
<td>Teacher can easily collect good</td>
</tr>
<tr>
<td>students will read description in</td>
<td>transparencies.</td>
<td></td>
<td>examples for later use.</td>
</tr>
<tr>
<td>Chinese.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw picture after hearing a</td>
<td>Overhead transparencies.</td>
<td>Tablet PC and Windows Journal.</td>
<td>Teacher can easily collect good</td>
</tr>
<tr>
<td>description.</td>
<td></td>
<td></td>
<td>examples for later use.</td>
</tr>
<tr>
<td>Students present pictures.</td>
<td>Overhead projector.</td>
<td>Virtual classroom and video projector.</td>
<td>Work is shared with the whole</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>class.</td>
</tr>
<tr>
<td>Teacher presents adjectives.</td>
<td>Overhead projector and</td>
<td>Tablet PC and PowerPoint.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>transparencies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students practice with adjectives.</td>
<td>Paper worksheet to be</td>
<td>Online worksheet to be turned in via SharePoint.</td>
<td>Work and time management</td>
</tr>
<tr>
<td></td>
<td>turned in the next day.</td>
<td></td>
<td>supported by technology.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11 The Chinese language textbook is not digitized.
In summary, changes to teachers’ lesson plans as a result of the introduction of the Tablet PC include the use of soft-copy documents shared with students, Internet-supported WebQuests, and the use of subject-specific applications. Implications for these changes include the possibility of easier sharing and reuse of resources, more student engagement, and more broad and open-ended activities.
Review of Projects Relevant to Tablet PC Use in Educational Settings

This section of the report draws on information from each of the documents listed below. For each document that was reviewed, we present its citation, a URL if available, and a description of each study’s scope and methodology. In those cases where the document is a primary research study, we present the purpose, scope, research questions, and method used in the study. The findings for these studies will be captured under the topical headings that are presented later in this section. In some cases, we have reviewed documents that are not primary research studies but rather are syntheses of prior research, historical accounts, or newsletters. In these cases, where new research findings are not included, we present the findings as part of the description of the study scope and methodology.

Citations, URLs, and Descriptions of Prior Studies

Research Report on Great Maine Schools Project on One-to-One Laptops


Description of Study Scope and Methodology. Piscataquis Community High School (PCHS) is located in Guilford, Maine. The school serves students in Piscataquis County, which is a rural area. At the time of the study, the high school enrolled 285 students in grades 9 through 12. According to the report, “In 2002, every student and teacher at PCHS received a laptop computer to use at home and at school, and the school was outfitted with wireless Internet access. The school’s curriculum is centered on heterogeneous grouping rather than academic tracking, and all students are expected to take a core college preparatory curriculum. This commitment to equity, rigor, and personalization of the curriculum was already in place at PCHS prior to the implementation of the laptop program” (Mitchell Institute, 2004, p. 1).

The study reflects the experience of those involved in the first 2 years of a one-to-one laptop computing program in a high school environment. The findings are valid for this high school but cannot necessarily predict the results of a statewide effort. Data collected included:

- Online surveys of all students and teachers at PCHS
- A mailed survey of all parents of PCHS students
- A review of administrative data for each of the past 3 years
- Interviews with 12 PCHS students, 4 faculty members, and the principal.

The research was designed “to investigate the extent to which the program has changed the learning environment, and to identify opportunities for further shifts in classroom practices and improvements in the curriculum at PCHS. This report was also produced to provide useful information to other schools, particularly high schools, considering implementing a one-to-one laptop program” (Mitchell Institute, 2004, p. 6).
Summary of 12 Case Studies of Tablet PC Use in England


Description of Study Scope and Methodology. The first report presents results of 12 case studies of schools in England that were using Tablet PCs. The analysis is complemented by brief individual reports describing aspects of how each of these schools was using Tablet PCs. The second report provides key findings from the literature.

Seven primary schools and five secondary schools (including one special school) were selected from more than 90 schools in England that were identified as using Tablet PCs in late 2004 and early 2005. All the case studies were guided by several key questions, including:

- Were there advantages to ownership?
- Why did schools buy Tablet PCs?
- What surprises did they encounter in introducing the Tablet PCs?
- To what extent were staff using the Tablet PCs for management, administration, planning, preparation, teaching, grading, record keeping, communication, or in other ways?
- What was the impact of Tablet PCs on the curriculum (what was taught) and how it was taught?
- Which students were using Tablet PCs, and when and where were they used?
- What was the impact of Tablet PCs on students’ learning (i.e., motivation, access to the curriculum, learning outcomes, and learning approaches)?
- Which features of the Tablet PCs were used, and what impact did these features have on practice in the case study schools?
- What were the infrastructural requirements and other technologies that were needed to significantly enhance the value of the Tablet PC and/or facilitate its effective use?
- What were the minimum and optimum levels of resourcing that were needed for the Tablet PCs to have an effect?
What levels of start-up and ongoing technical support are needed for students and staff to use the Tablet PCs effectively?

How easy did teachers and student find using the Tablet PC?

What are the relative pros and cons of Tablet PCs in relation to laptops?

When and where did learning with the Tablet PCs take place? To what extent were virtual spaces utilized?

What were the lessons that teachers learned from using the Tablet PCs?

Data were collected in late 2004. Each case study included collection of questionnaire and interview data with an ICT coordinator; an interview with a member of the senior management team; observations of two key Tablet PC users, who were then interviewed; collection of portfolios from the two key users that illustrate how they used the Tablet PC; logs of Tablet PC use collected by the two key users over a 2-week period; and additional interviews with the two key users to followup on the portfolio and usage logs.

**Research Report of “We-Learn”: Full Service Pilot Study of Tablet Use**


http://www.we-learn.com/pfi/LimitedServicePilot.shtml

**Description of Study Scope and Methodology.** The Full Service Pilot (FSP) study involved 18 teachers in four schools (two primary and two secondary schools) in England. The FSP aimed to have teachers in the pilot schools implement what was referred to as the “full solution.” The “full solution” included the use of Release 3 of the Teacher Toolkit (this included the Tablet PC, classroom PC, and projector) across a comprehensive selection of instructional activities and to gather technical, operational, and educational feedback that could be analyzed and acted on. The FSP training began in October 2004. Because of time constraints, the FSP was implemented before user acceptance testing of the teacher toolkit had been completed. This meant that some issues with the Release 3 solution were rolled out and experienced by the FSP teachers. This experience had a negative effect on the levels of use at some schools and the confidence in the solution by some teachers. Even so, around 200 lessons were carried out with the Teacher Toolkit, with 33 of these lessons observed by FSP mentors. Although not quite meeting the targets for use of 255 lessons, forecast at the start of the FSP, this should be seen as a great achievement and is a testament to the commitment of the FSP teachers.

Training was provided to all teachers and on-site mentoring and support for about 5 to 6 weeks to enable the teachers to complete a number of tasks by using the Teacher Toolkit. The mentors who provided support completed reports on all of their school visits. When teachers had completed their tasks, they completed a questionnaire that provided feedback on the activity. A larger number of schools were included in a Limited Service Pilot test.
Data collected included:

- Written evaluations of the training completed by 45 teachers who received only 1 day of training and written evaluations by the 18 teachers who completed 2 days of training and would be implementing the FSP more completely.

- Reports from mentors describing the tasks that the FSP teachers undertook.

- Documentation of the support calls generated during the FSP study.

- A questionnaire administered to each of the 18 FSP teachers that asked about hardware (Tablet PC, classroom PC, and projector), software and content, training, student response, support, and usage.

- Interview and questionnaire data from Limited Service Pilot schools.

This study was conducted to understand more fully the training, and mentoring of teachers, technical issues, and best working practices that are needed to optimize the start-up of a large-volume Tablet PC intervention.

**Action Research Report on Aberdeen City Pilot of Tablet PC Use**


http://www.ltscotland.org.uk/connected/connected9/ictinpractice/tablettrials.asp

**Description of Study Scope and Methodology.** Aberdeen City in Scotland has conducted a pilot of RM Tablet PCs (RM is a company specializing in the education market in the United Kingdom) in a variety of situations to understand the strengths and weaknesses of the technology and to identify those situations where it can be best used.

The first situation that was explored was the use of the RM Tablet PC by four pupils participating in a tour around local buildings. These students, like many others in Scotland, participate in discovery walks around the city with workbooks associated with environmental studies. Typically, students record information on clipboards, using their pencils. In this case study, the ICT development officer created an electronic version of the environmental workbook on the RM Tablet PC and encouraged a teacher to identify four pupils who might benefit from collaborating on the activity and being able to record automatically the information that they acquired during their tour. The four children chosen included a dyslexic youth and a child with a broken arm. The research question was to explore whether the RM Tablet PC technology “could increase confidence and enthusiasm and engage pupils who were reluctant to put pen to paper” (ICT Team, 2003, p. 1). The ICT officer observed the students using the RM Tablet PC during the tour and conducted a discussion with them afterward. The children were found to be very motivated by the technology, and all were desperate to get a turn. They experienced no difficulty using the stylus, and within a short period they were using the tablet imaginatively. Those children who did not have keyboarding skills found that this no longer created a barrier to producing an electronic piece of work. Technical issues were discovered, including how the use of an extended battery resulted in the Tablet no longer being able to be fit in the slip cover. The conclusion was that the benefits
of using the Tablet PC on field trips were greater than the disadvantages and that both teachers and pupils become mobile users.

The second situation in which the use of the RM Tablet PC was explored involved several Aberdeen City Council members who found the Tablet PCs particularly useful for note-taking at meetings and school visits. The City Council member would load an agenda document into the RM Tablet PC, and during the meeting he would make handwritten notes on the tablet, which were converted directly to text. The notes would be shared immediately after the meeting and digitally “signed off.” This practical solution increased the efficiency with which the written accounts of the meetings could be shared and agreed on; thus, the technology was greeted with enthusiasm.

The third situation involved an Aberdeen secondary school that had piloted eight RM Tablet PCs that were connected wirelessly to a server. The tablets had been used to access the Internet in selected classrooms and in the library. Some of the classrooms did not have network access points, so the wireless connection reduced the time students had to spend moving from classroom to classroom. The use of a Tablet PC by a school technician to record problems around the school found that the process can be done with more convenience than using a laptop.

Newsletter Article Synthesizing Results of Studies of Laptop Computing


Description of Study Scope and Methodology. This article is a brief synthesis of student results from four studies of laptop computing. Because the article is a synthesis and not reporting on results from a single research study, we will highlight the outcomes that Carter reports. The first set of results summarized are those of Rockman in which the Microsoft program titled Anytime Anywhere Learning Program was evaluated. This program provides hardware, content, training, and other types of support for schools implementing laptop programs. Key findings supply evidence that students with laptops “spend substantially more out-of-class time on schoolwork, score higher in writing and reading assessments, demonstrate improved research and analysis skills, and engage in more collaborative work than non-laptop students” (Carter, 2001). Similarly, second- and third-year evaluation results from Stevenson of the University of South Carolina demonstrate “that students with their own laptops have scored higher on standardized achievement tests than their non-laptop counterparts, with the most significant gains made by those in the free and reduced-cost lunch programs. Third-year results show all laptop students maintaining significant scoring advantages over non-laptop users” (Carter, 2001, p. 1).

At the Rio Bravo Middle School in El Paso, Texas, which serves predominantly students from low-income families, laptops were provided for all of its students, and the school has experienced dramatic, positive results. The laptop program, implemented through NetSchools, includes proprietary, infrared-equipped notebook computers for students and teachers; network hardware; and a year’s mandated training. One year into the implementation, according to Carter (2001, p. 1) “state achievement scores improved significantly, and student attendance rates increased to 97
percent.” The district that serves the Rio Bravo Middle School, encouraged by these results, planned to expand the program to every middle and high school by school year 2007.

Janice Gordon, the mobile learning coordinator from the Hartford Public Schools in Connecticut, is cited by Carter with regard to the impacts of laptop computing. Gordon associates a reduction (of more than 50%) in dropout rate of students after ninth grade with the implementation of a laptop computing program. Quoting from Carter (2001, p. 1), “Of the 267 students who started with the laptop program, 92 percent have remained in school and in the program.” Gordon, who stresses the qualitative results of the Hartford program, has seen the “change in self-image that disadvantaged students have when they're given the same technology tools being used by their suburban counterparts—and the business world at large. ‘We're fighting a faceless enemy in poverty, apathy, and student motivation,’ she says. ‘At the end of the day, when these students come out knowing they have tools that will take them beyond high school, they see themselves differently’” (Carter, 2001, p. 1).

In sum, this brief synthesis article, which lacks citations to the specific articles from which it draws its evidence, points to a relationship between the implementation of a laptop computing program and a variety of student and teacher outcomes. Specifically, it reports that students in laptop programs

- spend more out-of-class time on homework than their non-laptop counterparts,
- score higher on standardized tests of reading and writing than their non-laptop counterparts,
- improve their research and analysis skills more than their non-laptop counterparts,
- engage in more collaborative work than their non-laptop counterparts, and
- have increased home-school communication and more parental involvement.

In addition, it reports that laptop programs encourage teachers to move from traditional modes of instructional delivery to using instructional methods that are more individualized and more associated with discovery and interaction.

These results have to be regarded somewhat cautiously because the sources associated with the findings were not directly cited in the article; thus, we could not directly examine the findings and the methodology that was used to generate results.

**Review Article on History and Background of Tablet PC Use in Education**


http://www.nitle.org/resources/issues/tabletpc.htm

**Description of Study Scope and Methodology.** This article chronicles the appearance and development of Tablet PCs in education. Beginning with the introduction of pen computing in 1988 to the release of the first tablet input device for PCs, this article traces the history and form factors associated with the evolution of this technology. There have been several hardware manufacturers that have been active in the Tablet PC market—Acer, Fujitsu, HP/Compaq,
PaceBlade Technology, and Motion Computing. Regardless of the hardware, however, the user experience is dominated by Microsoft’s Windows XP Tablet Edition. This is “a complete version of XP Professional with some tablet-specific additions. Microsoft Journal is the new handwriting manipulation and recognition software designed to be used with the special electrostatic pens and LCD screens” (Condon, 2004, p. 1).

In the summer and fall of 2003, Microsoft and its partners tried out the Tablet PCs at three institutions of higher education—MIT, Bentley College, and the University of Texas at Austin. These sites provided feedback on the features and overall usability of the technology. Other educational institutions that provided feedback included professors and students from Purdue, Temple University, Kellogg School of Management at Northwestern University, Texas A & M University, and Seton Hall University. The reports from the educational institutions describe the courses in which the Tablet PC was used, the ways that students and faculty used the technology, the particular features that were used, the barriers to successful use, and the affordances of the technology.

Drawbacks that have been noted in educational settings include:

- Battery life of 2-4 hours.
- Tablet PCs are slower and less powerful than laptops.
- Need to be protected from dirt, and moisture, and no more rugged than laptops.
- Not convenient to use in long sessions of note-taking; keyboarding is faster and easier.
- Tablet PCs’ digital ink is a proprietary data type that can be read only by other Tablet PCs.

**Research Report on Impact of Tablet PC in a U.S. Middle School**


URL: not available electronically

**Description of Study Scope and Methodology.** This study was designed to examine how the use of Tablet PCs and an online curriculum affected students’ learning and attitudes toward learning, as well as parents’ attitudes toward learning and instruction. Reiser et al. (2005) state: “Through a partnership involving the Microsoft Corporation, Hewlett-Packard, and Harcourt Publishing, the Tablet PC along with a new online curriculum for the seventh grade were implemented in a pilot program at a middle school in central Florida. About 150 randomly assigned 7th grade students participated in the Tablet PC program, which involved 4 teachers (one each in language arts, science, social studies, and mathematics) in a single ‘pod’ within the school. All of the students and teachers in this pod were provided with a Tablet PC that they used to access the electronic version of the Harcourt curriculum. Approximately 300 additional students served as a control group in two other pods, one of which used a print-based version of the Harcourt curriculum while...
the other used the standard curriculum adopted in Oregon County. Both the standard curriculum and Harcourt curriculum are designed to meet Florida’s Sunshine standards” (p. 2).

The study was designed to examine the impact of the Tablet PC and electronic curriculum on teaching and learning. In particular, Reiser and his colleagues were interested in documenting the effect of the Tablet PC on

- student learning,
- student interest in and motivation toward school,
- student attendance,
- student behavior problems, and
- student technology skills.

The researchers were also interested in how students and teachers used the Tablet PCs in class and outside of class to see whether the “innovative and effective student-centered instructional practices and learning behaviors that technology-based instruction is intended to facilitate would occur” (Reiser et al., 2005, p. 2). In particular, the researchers were interested in seeing whether the students used the technology as an inquiry tool. Parents’ attitudes toward their children’s learning and the role of technology were also examined, as were teachers’ attitudes.

Students were randomly assigned to the Tablet PC condition or the control group. Data collected included classroom observations; parent, teacher, and student attitudes through the use of surveys, interviews, and focus groups; and student statewide achievement test scores.

**Topical Area 1: Form Factors: Tablet PCs versus Laptops in Instructional Settings**

In the case studies conducted for Becta by Twining et al. (2005), the key findings were that Tablet PCs, when used with a wireless data projector, provided a better instructional solution than the use of a desktop or laptop and hard-wired interactive whiteboard. In addition, Tablet PCs were seen as being more versatile than laptops, although the higher price of the Tablet PCs relative to similarly specified laptops was regarded as prohibitive. There was general agreement in the Twining et al. case studies and in the ICT Team (2003) pilot in Aberdeen, Scotland, that wireless networking contributed to effective Tablet PC use, especially given that many schools have classrooms that are not Internet connected.

Tablet PCs can be divided into two groups: slates and convertibles. Convertibles have attached keyboards and can be used in the traditional “clamshell” laptop configuration. Slates have no keyboard but can be docked to a keyboard if desired. In the Twining et al. (2005) study, both types of Tablet PCs were in use. In any given school, the number of machines ranged from 4 to more than 300. Schools varied as to whether they allocated Tablet PCs to staff or students and as to whether the machines were shared between users or “owned” by them. The amount of money and other resources that schools thought necessary for effective use also varied considerably, in terms of both the number of Tablet PCs needed and the amount of time that individual students needed to spend using a Tablet PC each week. These variations reflect each school’s vision for education.
Why do educators turn to Tablet PCs for classroom use? In the Aberdeen City pilot (ICT Team, 2003), the reasons for buying the Tablet PC becomes clear in the conclusions section of the article. “We like the RM Tablet PCs. They are not a replacement for traditional desktop computers but, with the improvements and additional peripherals which RM is producing, they offer greater flexibility than a laptop. The Tablet PC’s ease of use and flexibility make it a useful addition to a school’s ICT resources. As wireless networking becomes more established, the Tablet PC will find even more uses. Anyone who has used a Tablet to wirelessly control an interactive whiteboard will realise what a valuable device it is” (p. 3). Another perspective about the advantage of Tablet PCs over laptops in the educational setting is found in a quote from the Senior Management Team at Engayne School. Engayne is a primary school in England that was one of the case study sites for Twining et al. (2005). The Engayne Senior Management Team asserts that “Tablet PCs had enough of a future model about them but were not too far ahead, remaining compatible with the existing ICT knowledge of staff and pupils . . .laptops are dominated by keyboard-using skills and the stylus input of the Tablet PCs offered more intuitive potential” (p. 4).

In the 12 case studies, staff tended to use Tablet PCs in laptop mode, except when they were grading papers or when working with children. Students tended to use the pen, except when they did extended writing, for which they would use the keyboard. When using the pen for writing, students tended to use the on-screen keyboard or to leave their writing as digital ink. Few of the schools used handwriting recognition. Schools are likely to explore the potential of handwriting recognition further, given the enhancements in the 2005 edition of the Tablet PC operating system (Twining et al., 2005).

In terms of limitations, there were several common concerns about Tablet PCs reported in multiple articles. These concerns included security issues, robustness, battery life, screen size and glare, power and screen-saver settings causing the tablet to go into standby mode during lessons, cost of replacing pens, and the selection of software for use in particular curriculum areas (Twining et al. 2005; ICT Team, 2003; Condon, 2004; Hatton, 2004). Feedback from the Aberdeen pilot (ICT Team, 2005) pointed to problems with the life of the battery. At the time of that study, the battery supplied with the Tablet PC provided a nominal 3 hours of life and under steady use actually provided about 2 hours of support. This is less power than what is needed to support Tablet PC use for an entire school day. There is a larger battery available that provides five hours of use but adds to the overall weight of the Tablet. Aberdeen researchers commented that careful monitoring of Tablet PC use is required and an organized recharging regime must be devised to ensure that the tablets are always available when required.

Interestingly, in the Twining et al. (2005) case studies, much of the student work that the researchers observed could have been achieved with a laptop. However, the schools did not share this view. There was general agreement that Tablet PCs (in slate mode) were qualitatively different from laptops or other computers and that students related to them more intimately.

The following paragraph, quoted from Twining et al. (2005) summarizes how the case study schools compared laptops with Tablet PCs.

Most of the schools seemed to think that Tablet PCs had more to offer than laptops. This appeared to be related to the feeling that the Tablet-specific features, such as pen input and enhanced portability combined with other features such as wireless networking, and audio recording and playback, meant
that they were at the very least an ‘enhanced laptop’. There was a general feeling that their use was qualitatively different from the use of laptops or other computers. This was not reflected in much of the practice that the researchers observed, but several of the schools explained that this was because they were just starting to understand the potential and experiment with different ways of using them. (p. 18)

**Topical Area 2: One-to-One Computing**

Having an individual computer that a student can use at any time from any location creates more opportunities for students to engage in learning activities. Students can work on an assignment in whatever setting they choose, and the instructional resources that they use are not only those that the teacher provides or those that the students have on hand, but, with their own computer, they can access whatever resources are available through the Internet. Thus, one-to-one computing is believed to expand personalized learning opportunities for students, which should promote more student time on task and, ultimately, more learning. Results from the teacher, parent, and student surveys conducted by the Mitchell Institute (2004) found evidence that supports this claim.

Findings from the Mitchell Institute’s final report illustrate the increased interest, engagement, and attachment that students experience in having their own laptop. To paraphrase these findings:

Most students agree that laptops make schoolwork more interesting (79%) and that they are more motivated to do schoolwork with their laptops (60%) (p. 3)

The school has developed a list of ten policies and procedures for the laptop program. Students who violate the policies will lose their laptop for a period of time that the administration deems appropriate. In interviews, teachers mentioned that the consequence of losing access to a laptop was very effective in preventing student misuse (p. 4)

In terms of accessing information that is very personalized, this is clearly illustrated in the reports of the guidance counselors that one-to-one laptops provide students with better access to college and career planning resources, such as virtual college tours, SAT study guides, and online applications (p. 1)

When students have their own laptops, the ways that they approach their schoolwork changes and the activities in which they engage change, as well. For example:

86% of teachers and 49% of parents report that laptops have had a positive impact on providing students with more personalized learning opportunities.

68% of teachers and 61% of students report that ‘students explore a topic on their own’ more often since the laptop program began. In addition, 41% of students report that ‘students select their own research areas’ more often now, and 23% say that ‘student interests influence lessons’ more often since the laptop program began.

In open-ended survey responses about the best projects that have done using laptops, many students said things like ‘we get to design [the project] how we want to,’ ‘we have to make our own web pages and design and make them by
ourselves,’ and ‘we could do [the project] however we wanted, and they turned out really cool.’ (Mitchell Institute, 2004, p. 4)

The Mitchell Institute’s report cites results of two evaluations and one study that address the effects of one-to-one computing on teaching and learning. It cites an evaluation of the Maine Learning Technology Initiative (MLTI), which provided a laptop computer for each seventh and eighth grade student in Maine. This evaluation, which is being conducted by the Maine Education Policy Research Institute (MEPRI), “presented early evidence that one-to-one laptop computing has had positive impacts on teaching and student learning (MEPRI, 2003).” The second report indicates that a large majority of teachers and students reported increased student engagement and motivation, better interaction among teachers and students, and increased quality of student work. Although it is tempting to attribute these improvements to the laptop program, we must remember that these findings are based on teacher and student self-reports and are not findings from an experiment. Thus we cannot assert that the laptop program was responsible for the reports of improvement.

A second evaluation cited in the Mitchell Institute report was conducted by Saul Rockman and his associates (Rockman, 2000). This was a 3-year evaluation of Microsoft’s Anytime Anywhere Learning Program, which provides laptop computers, software, and training to middle and high schools. In Year 2 of the evaluation, the researchers found that those students who had their own laptops, compared with those students who did not have their own laptops, “participated in more project-based learning, produced more and better writing, had stronger research and analysis skills, and presented their own work more often” (Mitchell Institute, 2004, p. 6). The Mitchell Institute report (p. 7) paraphrases Rockman’s Year 3 evaluation findings as follows:

- Laptop students used computers more frequently and for longer periods of time, and used technology more flexibly and to a greater extent than non-laptop students;
- Laptop teachers changed their teaching practices (e.g., used student-led inquiry and collaborative work more often), while non-laptop teachers did not; and
- Laptop students performed better on writing assessments than others (Rockman et al, 2000).

The Rockman evaluation did not find significant differences between standardized test scores of laptop and non-laptop students. The lack of difference was attributed to the standardized tests not measuring attributes such as increased productivity, more effective writing, capacity to handle complex, real-world projects, and mastery of skills that will serve them well in college or on the job. The Mitchell Institute’s final report states that “Findings from the study’s [Rockman et al, 2000] teacher and student surveys and classroom observations suggest that full-time access to laptops stimulates analytical thinking and provides more opportunities for students to develop higher-order thinking skills.”

A third source of information that the Mitchell Institute cites on the effects of one-to-one computing is based on a study conducted by Stevenson (1998) in a county in South Carolina. Stevenson did demonstrate effects of laptop computers on students’ standardized test scores, especially for those students eligible for free and reduced-price lunch.
**Additional References Cited**


**Topical Area 3: Mobile Learning**

The mobility of the Tablet PC is one of its most powerful affordances. Articles describing the use of the technology include examples of use by students and teachers on field trips, on sports fields, in hospital wards, in large auditoriums and meeting rooms, and at home. Being able to hold the PC in one hand and input data with the stylus frees the user from having to sit a table to keyboard; with the Tablet PC, it is no longer necessary to be seated to enter information into a computer. This mobility allows the teacher to move about the classroom—the teacher no longer is “glued” to the front of the room. In addition, the teacher can illustrate student work via a wireless data projector. A teacher at the St. Francis case study school reported that “There are no restrictions on time or place, other than special curricular activities like swimming” (p. 19). The Senior Management Team from Engayne responded to the Tablet PC’s mobility as follows: “As a multi-site school the mobility has really strong appeal as the Tablet PCs offered anytime anywhere type use” (Twining *et al.*, 2004, p. 19).

Sheehy *et al.* (2005) summarized the range of uses for the Tablet PC as follows: “In some of the classrooms studied students used Tablet PCs to access materials such as video, web links or work sheets. In others the Tablet PCs were used with data projectors in place of interactive whiteboards. The portability and shape of Tablet PCs (particularly in slate mode) allowed students to move around, to collect data for example. Wireless networking facilitated their use in crowded classrooms. The most frequently reported use of Tablet PCs was in relation to handwriting: to improve skills, as an alternative to keyboard or mouse for interacting with a PC, and to save handwritten classroom notes as Microsoft Word or Journal documents” (p. 2).

In the 12 case study schools, 10 used the Tablet PC with wireless networking. The schools used the wireless networks to access the Internet, school servers, and printers and to install software. School staff in these 10 schools argued that wireless connectivity was “essential” and that if you did not have connectivity, it would “render them [Tablet PCs] ineffective” (Twining *et al.*, 2005, p. 13).

The advantages of Tablet PCs over laptops listed by Twining *et al.* (2005) provides additional information about how powerful mobility is as an affordance of the Tablet PC:

- taking up less space in the classroom.
- being more mobile, both in terms of being easier and quicker to pass around and also for writing on the go.
- providing a more natural way of working, both in terms of the pen/screen interface and greater flexibility about the positions in which they could be used (on your knee, on the desk, in one arm).
- using a pen being more intuitive, and easier than a tracker pad.
- being more robust (although several schools had problems with the earlier models) (p. 18).

Tablet PCs affect the physical and temporal spaces in which staff and students work—where learning occurs and to what extent virtual spaces are used. In the case studies, the use of tablets allowed rooms which had previously served as ICT suites to be devoted to other purposes, since the Tablet PC does not require all the wiring. Then the Tablet PCs permitted existing spaces, such as classrooms where ICT had not been able to be used, the playground, and the gymnasium, as well as spaces that lacked desks, to be used for instruction that involved computing. In addition, the Tablet PC supported learning outside the school and, in particular, supported learning at students’ homes.

Another research report that provided more detailed information about the Tablet PCs’ wireless connectivity was the Aberdeen City pilot (ICT Team, 2005). One of the Aberdeen secondary schools involved in the pilot had successfully connected eight RM Tablet PCs wirelessly to an RM CC3 server. Using this arrangement, the school was able to access the Internet in several classes and in the library. In several cases, the courses were taught in structures that were external to the school and did not have network access points, so the wireless connection on the Tablet PCs saved pupils from having to move to another room when they wanted to work on the Internet.

Information collected as part of the Aberdeen pilot indicated that the wireless connection can be slow when accessing the Internet, but this problem has been overcome in the latest version of the Tablet PC, which uses a faster connection speed.

**Topical Area 4: Teaching and Learning with the Tablet PC**

All of the studies that we reviewed on the Tablet PCs recognize the importance of studying the technology’s influence on learning and teaching. Subtopics of particular interest include the relationship of the Tablet PC to student motivation and engagement, student learning of academic content, and skills and ICT skills. In addition, many of these studies considered how Tablet PCs influenced collaboration among students and how teachers’ classroom practices were affected by the use of the Tablet PCs. In this section, we will address the following topics more carefully:

- Student motivation and engagement
- Student learning in academic areas
- Student learning of ICT skills
- Classroom practices and Tablet PC use
- Supporting collaboration using the Tablet PC.
Student Motivation and Engagement

Students enjoy working on the Tablet PC and report being motivated and excited by the opportunity to use the technology. Teachers’ reports of student enthusiasm and motivational levels concur with the student reports. Every study that was reviewed reported positive relationships between the use of the Tablet PC and student motivation and engagement in their classroom work.

The Twining et al. (2005) study concluded that the use of the Tablet PC had increased student motivation and hence was likely to have a positive impact on learning outcomes. Another example of the increased level of student engagement is found in the results of the Aberdeen City project. In the project, teachers observed students walking about on their field trips with their Tablet PCs and enthusiastically collaborating as they recorded their work. On discussing the work, the students were very proud of their accomplishments. The report concludes, “the Tablet has the ability to engage both teachers and pupils. It creates interest and curiosity; and it encourages independent learning. It will not replace the desktop computer but must be viewed as another tool to facilitate learning and teaching” (ICT Team, 2003).

In the Sheehy et al. (2005) summary of findings, one of the key benefits of Tablet PC use identified was improved motivation. The case study authors assert, “Pupils find Tablet PCs easy to use and are motivated to work using them.” Teachers cite this motivation as a significant factor in pupils’ academic progress, most frequently with regard to handwriting skills” (p. 1). The authors report, “They [Tablet PCs] were used extensively to encourage and support handwriting skills development for those children who experienced persistent or age-related difficulties with writing. Several schools reported that children found using the Tablet PC motivating and used them to practise and develop fine motor control skills” (p. 2).

Another example of how Tablet PCs increased motivation is demonstrated by the following quote: “Tablet PCs are an excellent tool for motivation. Pupils who previously have found curriculum areas difficult have attempted and reattempted tasks with energy” (Sheehy et al., p. 9).

The major success of the Full Service Pilot (Hatton, 2004) has been demonstrated in pupils’ positive response to working on the Tablet PC. All teachers have been very positive about the enthusiasm and interaction that has been engendered among students using the Tablet PC. Teachers report more variety in their instruction when they use the Tablet PC through the hardware, applications, content, and resources. Hatton reports, “All teachers were very positive about the response from the pupils to the use of the TTK [a toolkit that includes a Tablet PC controlling a wall-mounted PC and a data projector]. Of particular note was the increased interaction with the pupils and the variety in learning styles, which the teachers felt the pupils enjoyed. The teachers also felt that the toolkit provided a ‘wow’ factor with pupils, who were impressed with the new technology and that they were engaged because of the variation in teaching and learning styles that was achieved with the toolkit” (p. 24). The following quotes from teachers capture pupil response to the technology:

“Children find it fascinating, stay focused for much longer.”

“Those children who have difficulties stay focused for longer and are eager to have a go.”

Pupils respond “in a super way.” (Hatton, 2004, p. 27)
Student Learning in Academic Areas

Results from the Mitchell Institute (2004) report provide evidence from self-reports that most students and teachers believe that the laptop program has improved the quality of student work and has had a positive impact on student achievement. Seventy-one percent of students report that laptops have improved the quality of their schoolwork, and 54% agree that having a laptop has improved their grades. Sixty-four percent of teachers report that since the laptop program began their students’ work has improved, and most report that laptops have improved the quality of work, particularly for students they define as at risk or low-achieving. Forty-two percent of parents say that laptops have had a positive impact on the quantity and quality of what students learn in school, and nearly 38% report that their child’s grades have improved since the laptop program started. These findings are about the influence of laptops, not Tablet PCs, on student learning. Nevertheless, considering how laptop’s are related to student learning provides a point of comparison for considering how Tablet PCs influence student learning. These findings, which are self-reports, have not been corroborated by examining test scores or school grades.

Tablet PCs are newcomers in classrooms compared to laptops. Thus, we do not know what impact they will have on student progress. In the prior section of this report, we reviewed results of parents’, teachers’ and students’ self-reports which indicate that the Tablets do have an affect on student motivation. We argue that if students are motivated to learn it is more likely that their performance will affect their academic attainment. In one of the Twining et al. (2005) case studies, a teacher from St. Willibrord’s, made the following observation about children’s learning using the Tablet PC, “Their [the children’s] researching has greater depth as they now consult a wider number of sources . . . learning is more in the classroom and less in the ICT suite and is more ‘hands on’—that is not just listening to or watching teacher presentation—learning is more multisensory and kinaesthetic . . . . There is much greater use of ICT and they are certainly more competent and confident ICT users but it’s a bit early to say about other areas” (Twining, p. 22).

Another example of how student learning was affected by the Tablet PC is found in St. Mary’s RC Primary School, another case study in the Twining et al. (2005) case studies. At St. Mary’s, a rural primary school of 79 pupils, the children used the Tablet PC in literacy in the Year 2/3 class. Four pairs of children were selected to use the Tablet PC and received support from a teaching assistant. They used a storyboard template with prompting questions (available through the Journal application). The children used the pen to complete the template. Each pair of students decided what to put in the boxes and remained on task for the entire 30 minutes. The classroom teacher specified the following advantages of using Tablet PCs for this activity:

- Finished work is legible, clear, and neat.
- Ideas can be changed easily.
- The children are motivated by using the new technology.

This same teacher used the Tablet PC in another activity to conduct an “adjective hunt.” After identifying the adjectives, the students wrote their names on a list on the Tablet PC in the Journal application. The teacher then conducted a feedback session, using each Tablet PC with the data projector to discuss the adjectives that were found. She concluded that the use of the Tablet PC helped her validate students’ work and provide feedback quickly. It also helped her identify and correct any misconceptions and identify any students who needed further work.
The case study summary concludes with key lessons learned. The first lesson captures the teachers’ sentiments about the effect of the Tablet PC on students’ learning: “Tablet PCs opened up new ways of working. In particular they could encourage different teaching styles and support different learning styles” (p. 27).

Reiser et al. (2005) conducted an impact study documenting the effect of Tablet PCs on student achievement as measured by nine subtests of the Florida Comprehensive Assessment Test (FCAT). The FCAT is the state’s standardized achievement test, which is administered near the end of the school year and is designed to measure student skills in reading and mathematics. Reiser and his colleagues randomly assigned 150 seventh grade students into an instructional ‘pod’ consisting of four classrooms (one each in language arts, science, social studies, and mathematics). These students and their teacher received a Tablet PC, which they used with a Harcourt online curriculum. Three hundred students were in the control group and were members of two other instructional pods. One pod used a print-based version of the Harcourt curriculum and the other used the standard curriculum that was adopted in Orange County. A comparison of the treatment (Tablet PC) and control conditions revealed that for two of the nine FCAT subtests (research/reference skills and algebra), the students in the Tablet PC condition scored significantly higher (p=.02 and p=.004). Although this study provides evidence of increased learning in the Tablet PC condition, it is possible that because teachers were not randomly assigned to Tablet PC vs. control classrooms, the significant effect may be due to differences in teachers.

The maturity of the research on the effects of laptops and Tablet PCs on student learning differs. More research has been conducted on the effects of laptops (see Rockman et al., 2000; Mitchell Institute, 2004; Stevenson, 1998) than has been conducted on Tablet PCs. An important focus for future research will be to conduct studies of the impact of Tablet PCs on student learning and disaggregate the results to see the technology’s impact on different groups of students.

There is a need to study the differential effects of Tablet PCs on learners with different levels of prior achievement or socioeconomic status. Research on laptops supplies some evidence that, although laptops have been shown to affect all students positively, the greatest improvements have been for at-risk or low-achieving students (Mitchell Institute, 2004). When asked how laptops have affected three groups of students—“traditional,” “at-risk or low-achieving,” and “high-achieving”—teachers in the Great Maine Schools Project were most likely to state that laptops assisted the at-risk or low-achieving students to make the greatest number of improvements in performance. In interviews, some of these teachers observed that one-to-one laptops have helped to “level the playing field” at school or have minimized differences between “haves and have-nots” (pp. 21-22). Likewise, Stevenson (1998) demonstrated in his study of a middle school laptop program in one school district in South Carolina that students who are eligible for free or reduced-price lunch benefited more than other students, in terms of increases in standardized test scores.

The finding that low-achieving students benefit more from one-to-one computing is not to say that teachers believe that high-achieving students do not improve with exposure to the technology. In the survey conducted by the Mitchell Institute (2004), although teachers are least likely to indicate that laptops have helped students they consider high-achieving to make improvements, perhaps because these students have the least room for improvement, they do not report declines for these students as a result of laptop use. In particular, a majority of the Great Maine teachers report that high-achieving students with exposure to laptops demonstrate improved interactions with teachers.
(71%), improved interactions with students (57%), increased engagement and interest in school (55%), and increased quality of work (52%). Further, student survey responses indicate that laptops may be providing additional learning opportunities for higher-achieving students.

**Student Learning of ICT Skills**

Tablet PCs increase ICT use. Data from student and parent surveys conducted by Reiser et al. (2005) indicate that students in the Tablet PC condition, when compared with their non-Tablet PC counterparts, believed that their computer skills had greatly increased during the prior year. Likewise, parents of students with the Tablet PCs, when compared with their non-Tablet PC counterparts, were more positive about the extent to which their children’s computer skills had improved. In the Reiser study, the researchers used an observation instrument—the School Observation Measure (SOM)—to observe the degree to which various innovative practices were in use. The students in the Tablet PC classrooms used computers as a learning tool (i.e., to obtain, manipulate, and communicate information to complete an instructional task) to a greater extent. In addition, students reported “learning new skills such as the ability to access resources to search and locate information, and they were observed to teach these skills to their peers” (p. 4).

The Sheehy et al. (2005) summary of key findings reported that the use of Tablet PCs influenced schools in a variety of ways. One way that it changed the learning environment was to influence a school’s decision to shift from a “fixed ICT suite” to using ICT in the classroom. “In one case, Tablet PCs were used to deliver discrete ICT teaching but in the main classroom. In others, it influenced a change to teaching ICT skills as an integral part of the other curriculum areas” (p. 3). A quote from a primary head teacher in one of the case study schools provides the following perspective “This [implementing the Tablet PC] is not just an issue of adding new equipment, it is indeed a complete paradigm shift, as we see the benefits of this equipment to support the embedding of ICT across the curriculum as well as improving communication and sharing of documents” (p. 5). Tablet PC use increased the amount of ICT use and the degree of integration of ICT across the curriculum.

Several of the studies reported on how easily and intuitively students learned to use the Tablet PC and enhanced their ICT skills in doing so. “Where students had ownership of a Tablet PC the Tablet PCs were in use for more of the time than when Tablet PCs were shared between classes. Twining et al. (2005) point out that “Students quickly learned how to operate the features specific to the Tablet PC, building upon their existing ICT skills” (p. 3). Tablets are described as having “enough of a future model about them but were not too far ahead, remaining compatible with the existing ICT knowledge of staff and pupils. Laptops are dominated by keyboard using skills and the stylus input of the Tablet PCs offered more intuitive potential” (p. 4). From the overall case study results, it was evident that teachers had observed an increase in ICT skills related to the amount of Tablet PC use and that, with Tablet PCs in use, ICT was much more integrated within the curriculum. Even in those classrooms where students shared access to a Tablet PC, the technology was able to effectively replace an ICT suite, creating more space and increasing the amount of ICT in which students were engaged and the extent to which it was integrated in the curriculum.
Classroom Practices and Tablet PC Use

As in the area of student learning, the Tablet PC research literature is still relatively limited. Thus, we turn to the research results on one-to-one computing to get a sense of how these technologies have influenced classroom teaching. Results from the Great Maine Schools Project (Mitchell Institute, 2004) reveal no major shifts in teaching practices since their laptop project was initiated, but several indications point to emergent changes. Presented with a list of 16 classroom practices, the Maine teachers identified 2 classroom practices that occurred more frequently since the laptop program was initiated: “students explore a topic on their own (68%)” and “students teach the teacher (57%).” Students, but not teachers, reported that they “write more than one page more often now,” that they “select their own research areas more often now,” and that they “work in groups more often now” (p.19). Nearly three-quarters (73%) of Great Maine Schools Project teachers agreed that their role in the classroom had changed since the laptop program started.

When Great Maine Schools Project teachers were asked about the three most commonly cited disadvantages of using laptops in the classroom, they identified the following:

- Potential for distraction in the classroom.
- Non-educational and/or inappropriate laptop use by some students.
- Technology failure that interrupts planned class activities. (p. 23)

There is no single classroom practice that the majority of students or teachers reported as occurring less often since the inception of the laptop program. However, 41% and 45%, of students and teachers, respectively, report that “a textbook is the primary guide” less often since the laptop program began (pps. 12, 18). Students in 12th grade are more likely than students at lower grade levels to report that “direct instruction” occurred less often since they received laptops (32% compared with 13%) (p. 13).

The object of the study in the Great Maine Schools Project was, as specified earlier, the laptop computer, not the Tablet PC. Two helpful sources of information on the relationship between the Tablet PC and classroom practice are found in Reiser et al. (2005) and the case studies by Twining et al. (2005). Reiser et al. used the School Observation Measure to document how often various instructional practices were being implemented in classrooms. For most of the instructional practices that were observed, there were no significant differences in their frequency of occurrence in the Tablet PC classrooms vs. the control classrooms. However, one way in which the experimental and control classes differed was the extent to which the students in the Tablet PC condition were using the computer as a learning tool (to obtain, manipulate, and communicate information for the purposes of completing an instructional task). Students in the Tablet PC condition used the computer as a learning tool more often than students in the control classrooms.

The Resier et al. (2005) paper, in its conclusions, cautions, “Taken as a whole, the results presented in this paper indicate that the promise of Tablet PCs for benefiting teaching and learning is clearly evident, but these potential benefits were not fully realized in this study. In order to increase the positive impact that Tablet PCs have on instruction and learning, training and support for those teachers who will be using the Tablet PCs in their classrooms must be expanded. It is often the case that when new technology is placed in classrooms, teachers receive a minimal amount of training (Cuban, 1986; Tyack & Cuban, 1993). As a result, it is not surprising that the
nature of the instructional activities in the Tablet PC classrooms, particularly with regard to the use of some student-centered instructional activities, was not markedly different from that which took place in the control group classrooms” (Reiser et al., p. 5).

In the Sheehy, et al. (2005) summary, four broad ways of extending classroom practice with Tablet PCs were identified: (1) as an interface for digital art; (2) continuity of use between school and home; (3) improved communication among students, teachers, and parents; and (4) integrating ICT in the curriculum (pp. 3, 9). In three of these areas (1, 2, and 4), the way that instructional practice would be extended is obvious. However, the ways that communication could be extended in classrooms via the Tablet PC could vary greatly. Sheehy et al. list seven ways that the Tablet PC has been used to change instructional practices related to communication:

- Convert handwritten notes into typed text or, in Journal, to draw diagrams easily before annotating and sharing them.
- Construct and share diagrams and mind maps, without losing their original format.
- Create and perform whole-class presentations (in conjunction with a data projector) with ease.
- Make marking [grading of papers] and administration more efficient (for example, the transport of books or folders of work could be eliminated and pupils ‘handed in’ homework in electronic form which was annotated with handwritten comments).
- Provide audio comments on pupils’ work, thus improving communication with parents (one school).
- Link with a docking station and data projector so that students could easily lead the class and/or share work, from their own Tablet PCs.
- Support flexible use through built-in wireless networking capabilities (in conjunction with a wireless network infrastructure) (p. 9).

Paperless courses become an option in schools that are implementing the Tablet PC. Another positive affordance of the Tablet PC is captured by the following quote from a secondary school teacher, “Sharing handwritten notes and drawings personalises communication, and the ‘richness’ of the ideas can be communicated to others.” (Sheehy et al., 2005, p. 9)

Many of the case study schools reported that they now taught ICT skills in context, rather than in isolation. These schools also reported that students’ general level of ICT competence had increased, but all of the schools recognized that they were just beginning to learn how the Tablet PC could be used instructionally to best advantage Twining et al. 2005 (p. 4).

Professional staff at case study schools identified the ownership of the Tablet PC as a very important determinant of how much impact the Tablet PC had on staff usage. When staff could use a Tablet PC extensively—even if they had limited teaching time—it increased their ICT confidence and competence. Many staff reported that the use of the Tablet PC influenced their pedagogy, “resulting in more independent work, often based around research using the Internet” Twining et al. 2005 (p. 5). A key finding of the case studies was that the Tablet PC supported teachers in creating a learning environment in which students could be more independent in their
study and engage in more collaborative work. The Tablet PC supported the use of more multidisciplinary curriculum organized around topical activities. The Tablet PC can be used to project shared work, which means that the whole class can participate in a lesson, but that individual student work or group work can be shared and addressed. There were reports of classrooms that shared math games via the Tablet PC. At Engayne School, the ICT consultant reported, “They [students] love the Tablet PCs. Using maths games as a whole class has motivated them to improve mental and oral numeracy skills as a starter” (p. 9).

Twining et al. (2005, p. 6) identify three levels of impact that the Tablet PC can have on the curriculum:

- **Support** – increasing efficiency without changing the curriculum.
- **Extend** – the curriculum is changed, but this could have been achieved without Tablet PCs.
- **Transform** – the curriculum is changed, and this could not have been achieved without Tablet PCs.

One conclusion was that use of Tablet PCs increased the pace of lessons and the richness and variety of the content that was being presented. In most cases, the teachers used the Tablet PC to support and extend classroom instruction. Only in a small number of cases, was the use of the Tablet PC described as transformative, and in those cases, it was often being used to extend learning beyond the formal classroom context.

**Supporting Collaboration Using the Tablet PC**

Several research studies indicate that one-to-one computing does foster interaction among students and between students and teachers (Lane, 2003; Mitchell Institute, 2004; Rockman, 2000). More than 70% of teachers in the Great Maine Schools Project (Mitchell Institute, 2004) study reported that the laptop program had improved student interaction with teachers, and that it had improved interaction among students they defined as traditional, at-risk, or low-achieving. Particularly for at-risk or low-achieving students, laptops improved students’ skills at working in groups.

A number of students reported that laptops make it easier and more efficient to work in groups, because assignments can be divided and there are more mechanisms for communicating with group members. Several teachers noted that laptops have provided a way for students to have social contact with those who they would normally not interact with, or that laptops have given shyer students a safer avenue to express their opinions and engage in the school environment.

The Tablet PC literature, limited as it is, also supports the occurrence of greater collaboration among Tablet PC users. A key finding of Twining et al. (2005) was that the Tablet PC supported more collaborative activity in classrooms (p. 1). The case study schools found, in general, that the Tablet PC was being used to develop group work and collaborative activities in classrooms. Tablet PC affordances that support collaboration include:

- Networked sharing of information.
- Pen input as a means of brainstorming and increasing opportunities for discussion of joint problem-solving tasks.
- Storing and accessing a wide range of work electronically, avoiding the difficulty of sharing hard copies.

- E-mailing information to other students, making them less reliant on the teacher as an information source.

- Saving work to a shared network area and accessing it when needed.

**Additional References Cited**


Conclusions and Future Work

In its Second Master Plan for IT in Education, Singapore’s Ministry of Education identified six desired outcomes of its vision for technology use in the nation’s educational system. Goals have been established at the school, national and global levels to guide mp2’s implementation and monitor its success. These goals are based on the premise that a supportive pattern of interactions will be developed between students and teachers and that the resulting positive relationships will be coupled with a coherent curriculum, assessment and instructional package that has been infused with technology. This combination of enhanced relationships, powerful technology and well-designed curricular experiences should result in “engaged learning” for all students. When students are engaged in learning, they are likely to acquire more information about a topic. Presumably, engaged learning would result in the acquisition of not only facts and principles, but also procedural skills that are needed to use the information and strategies about when these procedural skills should be applied.

Recognizing the import of the mp2 plan for students and teachers, the conclusions of the current study are considered in light of the mp2 outcomes12.

- Pupils use IT effectively for active learning.
- Connections between curriculum, instruction and assessment are enhanced using IT.
- Teachers use IT effectively for professional and personal growth.
- Schools have the capacity and capability in using IT for school improvement.
- There is active research in IT in education.
- There is an infrastructure that supports widespread and effective use of IT.

Relevant conclusions from the current study are discussed in the context of these outcomes with the exception of the outcome on school improvement. (We did not collect data on this topic.) The conclusions should be interpreted with caution because they are based on self-report data, not observational or experimental data. While the guarantee of anonymity of the survey responses can produce data that is more representative of actual practice and experience, conclusions drawn from self-report data are viewed as more subjective than actual student test scores or observations of classroom practices.

Pupils use IT Effectively for Active Learning

Students are effective users of technology. Students in the Tablet PC program are sophisticated users of technology. Their prior IT proficiency and home technology resources do not impact their attitudes, but, as previous research has also shown, their ownership of the Tablet PC supports them incorporating it into many facets of their education. They have become skilled users of the Tablet PC and its applications for learning: note taking, journaling, creating drawings and art, Internet research, and collaboration. Students reported experience with varied Tablet-PC-based applications to accomplish these tasks, and also use custom applications for subject-matter learning. Teachers reported on students’ novel use of the Tablet PC in support of organizing their

---

studies and completing assignments, suggesting that students are able to go beyond what they have been taught in ICT skills. Future work should confirm the relationship between one-to-one, mobile learning and the development of 21st century skills.

**Convenience is an important factor.** Convenience emerged as an important factor in use of the Tablet PCs. Convenience supports ‘appropriation’ of technology into everyday practice in that it signifies ready availability and utility in many situations. Students want the Tablet PC used in all of their classrooms. Thus, applications that span subjects are important.

One source of inconvenience comes from the form factor of the hardware these students are using. Weight of the machine, slow speed, and short battery life make the Tablet PC less convenient than, for example, a mobile phone or PDA. Another source of inconvenience is from ‘buggy’ applications—those that were developed especially for use with the Tablet PC program in Singapore and which had not yet undergone rigorous testing. CGS students in this study were tolerant of errors in these applications, and there is some evidence that the students that were earlier in their implementation (i.e., CHS) were not. We also believe that students in Secondary Three and Four will be intolerant of mistakes, given their drive to prepare for high stakes testing.

**Anytime learning supports active learning.** The Tablet PC supports active learning in part by giving students 24 hour access to new content via digital textbooks and the Internet. Thus, students have much greater independence as to how, when and where they will pursue their assignments and academic interests. In addition, the Internet access provides them with a range and quality of resources unheard of a decade ago. The portability of the tablet permits students to take the technology into museums, libraries, playgrounds and record data, make observations, and write about their experiences in real time. Students are able to take their Tablet PC home and continue working on the projects and schoolwork at convenient times. Thus, the Tablet PC technology supports anytime, anywhere learning and facilitates students being “in charge” of their learning activities in ways that were impossible even a few years ago.

**Engagement with learning material can aid learning.** The Tablet PC supports making connections among digital content, and this feature offers the potential for students to engage more with learning resources. Students can annotate their digitized textbooks and the PowerPoint slides that teachers use for instruction and can make links between textbook content and external resources such as Web sites and documents. In this way, students can “make the materials their own.” They can work directly with the materials and thus there is a more intimate connection between the content and the instructional activities. Drawing diagrams such as mind-maps can engage visual learners. Making connections and summarizing relationships using mind-maps may help students to be more aware of their role as learners and to reflect on their own knowledge to self-regulate their learning (Bransford, Brown, & Cocking, 1999). Future work in this area could confirm and clarify the Tablet PCs impact on learning “big picture” ideas using this linking feature.

**The tablet form factor is important.** Previous studies, and this one, have shown differences in the type of human-computer interaction that is possible with a tablet computer. The range of learning activities that students can engage in using the Tablet PC is greater than what they can do with a laptop due to the stylus input, inking, and handwriting recognition. The Tablet PC seems to facilitate a more direct interaction between a student and learning material. There is evidence emerging that differentiated learning is occurring as student use the Tablet PC in ways that are
suited to their interests and capabilities. Students are encouraged to be independent learners because of the Tablet PC’s ready access to many resources. Yet these are tentative findings that bear further research. While it may be difficult to conduct an experimental design that compares, for example, laptops to tablet computers, it may be possible to conduct meta-analyses on the data collected in different studies to isolate the impact of the tablet form factor.

**Connections among Curriculum, Instruction and Assessment are Enhanced Using IT**

**ICT skills are taught in context.** Results of our research (and of prior studies) indicate that learning about ICT is more integrated into the subject areas. In programs like the present one, ICT skills are taught in the context of learning a topic area, and students can use these skills effectively for learning purposes. Given this, one would expect to find ICT use that is directed toward learning, self-expression, and inquiry. Our results bear this out: elicitation of student responses to open-ended questions about how they plan to use the Tablet PC focused mainly on school-related activities, which suggests that the main future uses that students see in the Tablet PC are connected to the improvement of their education.

**Instruction changes in response to/in concert with technology.** While changes in instructional methods were reported at both schools, the introduction of technology is only partially responsible. Both schools saw the need for teachers to change their instructional methods in response to the need to focus more on knowledge application, innovation, and creativity. Teachers felt the need to update their lessons to make them more engaging to students, and it is clear that the Tablet PCs helped in this regard. Although it can appear that the Tablet PC takes “center stage” in the program, in fact it was folded into these changes as one more tool to accomplish the desired outcomes. Future research might investigate more specifically the ways in which the Tablet PC supports changes in pedagogy. This could be done by considering the different ways that teachers can incorporate information technology into lessons (replacement, evolutionary, and revolutionary) by examining change to both the content and type of instructional activities, and to measure whether teachers expect a higher-level learning outcome from the students as a result.

**Impact on low-achieving students.** Some evidence has emerged that some teachers do not believe the Tablet PC program is of benefit to low-achieving students. This could be due to the potential for distraction from learning tasks or to differing interpretations of “low-achieving” in the survey. Teachers may have thought that “low-achieving” meant “misbehaving.” Teachers believed that high-achieving students learned regardless. This suggests that careful consideration be given to Tablet PC activities when implemented in other schools. Pilots should be run to ascertain the cause of this difference and/or CGS and CHS teachers could be interviewed or surveyed to seek further clarification of their interpretation and responses.

**Assessment is an important area for future work.** Evidence emerged in our study for increased use of formative assessment using a classroom response model. For example, tools such as the Virtual Classroom application allow a quiz can be delivered to each student and each student's response can be made available to the teacher at once as individual and aggregate responses. Research on-going in this area describes the impacts of classroom response and communication systems in terms of (1) support for formative assessment through questioning and feedback, (2) building concepts through contrast and student discussion, and (3) a shift to mastery-oriented motivational incentives (Roschelle, Penuel, & Abrahamson, 2004b). This is clearly the next needed step in the Tablet PC program in these schools and will move teachers toward designing
lessons and activities that allow for tailoring based on feedback from students, using their expertise to adapt to feedback, and making the Tablet PC an integral part of more interactive lessons.

In addition to classroom response system models of assessment, the Tablet PC form factor supports novel forms of assessment such as recorded speech, music, and singing. Teachers can access students’ assessments digitally, and often, teachers can grade students on processes they have demonstrated even if the right answer is not obtained. One-to-one computing supports extended project work, and these schools have emphasized project work and application of knowledge as ways to assess student learning. Having assessments done on a personal computer means that a digital portfolio can be built up over the years of secondary school. This can be used not only for review for exams or as a resume for entry into post-secondary studies, but also by the student to monitor their own learning.

**Teachers use IT Effectively for Professional and Personal Growth**

**Preparation time could be minimized by sharing resources.** Teachers find satisfaction in keeping up with the times; they feel a push from their students that fuels their professional growth toward the use of IT. But it can also be stressing—teachers acting as facilitators in a learner-centered classroom means more preparation time. Yet the possibility exists for teachers to learn from others because electronic artifacts (e.g., lesson plans, assignments, samples of student work) can be shared and archived. School portals make this easier. Portals are public and encourage reuse of materials and continuous improvement. This publicity may be uncomfortable for experienced teachers who are used to the privacy of the classroom, whereas it may give new teachers a significant boost in their entry into the teaching profession by providing resources for review, a venue for feedback on their lesson plans, and facilitating networking with their peers.

Future work could look at how teachers adapt existing materials and how systems can be put into place for recognition of teachers who contribute quality materials.

**Teachers’ creativity can be expressed using the Tablet PC.** Teachers can see the possibility for being creative in developing lessons and activities for students after learning basic skills in how to use various applications. Teachers reported that they presented content with PowerPoint and that they expected their students to use it also. Teachers felt positive about PowerPoint because students use more pictures and drawings in their presentations. PowerPoint also can bring teachers’ presentations to life so that students can see a concept immediately, although a few teachers felt constrained to a linear delivery of material.

While the weekly sharing lessons were generally felt to be useful, teachers still want more advanced training in using the tablets pedagogically. Lessons emerging from the use of the Tablet PC in higher education (e.g., Anderson, Anderson & McDowell, 2005) should be reviewed for techniques that apply to secondary schools.

**Classroom management is the most immediate issue.** Creating new classroom practices and successfully managing a classroom given the presence of a potential distracter is the first issue that teachers face and deters smooth adoption. It is harder to manage a classroom when each child has a “window to the world” through which she/he might stare instead of attending to class. Of CHS teachers who completed the survey, twenty percent strongly agreed and sixty-five percent agreed that “it is harder to manage my classroom.” This finding could be related to length of
implementation: at CGS only fifty percent agreed with this statement. Teachers try to manage
distractions primarily by telling students when they can and cannot use it: ninety-one percent of
CHS students and eighty-four percent of CGS students reported this about their teachers. Yet the
qualitative data showed that good teachers try other motivators and strive to make the issue one of
improving students’ character by helping them self-regulate.

There is Active Research in IT in Education

While we did not review all of the educational research taking place in Singapore, the
administration at CGS reported working with a researcher in Singapore to understand learning
styles and to conduct research on the Tablet PC implementation. The school also has adopted the
view of teachers as researchers, using action research as their general methodology.

The present study also exemplifies the attention to both descriptive and analytic methods to
technology in education in Singapore. Scaling up studies such as this one can provide more robust
conclusions on which to base policy for future implementations.

There is an Infrastructure that Supports Widespread and Effective Use of IT

In Singapore, the infrastructure that supports IT is not just technical, but also social in nature. The
social infrastructure goes beyond making technical resources (e.g., wireless connectivity)
available, rather it reinforces and nurtures users of IT through Singapore's many cultural
institutions, including the home. These institutions establish environments that support learning,
both formally and informally. Some of them provide resources for students to learn new ideas and
content, others offer students new experiences, and still others simply provide a setting where
students use IT to gather information, think about ideas, and learn without interruption. All of
these settings support the use of technology, the importance of learning, and a recognition that
high levels of productivity are needed for survival in today's world. These supportive institutions
are not only schools, but also libraries, museums, community centers, and even the fast food
restaurants, such as McDonald's, which make Internet access available. Parents' support of
technology is also crucial. The fact that Tablet PCs can be taken home by students and used for
academic, extracurricular, and recreational interests is a great impetus to students' proficiency with
ICT and their familiarity with the resources and databases available.

As prior research and this study have documented, there is a knowledge base regarding the
technical infrastructure that needs to be provided for successful use of the Tablet PC. Teachers
need professional development on an ongoing basis to be able to use the Tablet PC, relevant
applications, and a projector in tandem for instructional purposes in classrooms. Wireless
connectivity should be available. Batteries and additional replacement pens need to be available so
that the technology can be used without interruption. IT specialists should be available to provide
backup in schools throughout the scale up of the Tablet PC.

Industry partners were an important part of the Tablet PC program at these schools. Hardware,
networking, and textbook companies participated, and software companies worked with CGS to
generate ideas for Tablet PC educational applications. Thus, in addition to the more standard
productivity applications that are useful for capturing, locating, organizing, and presenting
information, applications in subjects such as mathematics, Chinese language, and science were
developed and used at one or both schools. Software for classroom management and information
organization was also developed and used in these schools. School portals for information sharing
were used at each school to promote sharing among school staff and communication among the administration, teachers, and students. These content and productivity applications create the software infrastructure needed for effective use. Future work in this arena should include applications that teach hard-to-grasp concepts through modeling and simulation, and enhanced formative assessment tools linked to the curriculum.

**Conclusion**

The students in this study find working with the Tablet PC engaging and see tablet computing as a natural extension of the media-rich, portable-, and pervasive-computing world they inhabit. They enjoy the self-expression afforded by the escape from text-only input. Internet access provides the ability to explore the world at will. Ownership of the Tablet PC is a strong determinant for how much learning students and teachers report, and mastery of the technology skills enables more sophisticated use. Tablet PCs have been shown to support and to extend instruction, and future research is seeking to determine if they can be truly transformative to day-to-day life in classrooms.
References


