Quantity versus quality: A new approach to examine the relationship between technology use and student outcomes

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Abstract

The author argues that to examine the relationship between technology use and student outcomes, the quality of technology use—how, and what, technology is used—is a more significant factor than the quantity of technology use—how much technology is used. This argument was exemplified by an empirical study that used both angles to examine the association between technology use and student outcomes. When only the quantity of technology use was examined, no significant association was observed. However, when the quality of technology was examined by investigating the specific types of technology uses, a significant association was identified between technology use and all student outcomes. Furthermore, different types of technology use showed different influences on specific student outcomes. General technology uses were positively associated with student technology proficiency, while subject-specific technology uses were negatively associated with student technology proficiency. Social-communication technology uses were significantly positively associated with developmental outcomes such as self-esteem and positive attitude towards school. Entertainment/exploration technology use showed significant positive association with student learning habits. None of these technology uses had significant influence on student academic outcome. Specific suggestions for integrating technology into schools and future research were provided.

Introduction

In the last two decades, generous investments have been made in educational technology around the world. For example, the US had invested more than $66 billion in school technology in just 10 years (Quality Education Data, 2004). By 2004, China had spent 100 billion Yuan (about $13.2 billion) on educational technology (Zhao, 2005), and

the annual expense on educational technology was projected to reach 35.5 billion Yuan in 2007 (Okokok Report, 2004). Ireland's second national educational technology plan proposed to invest 107.92 million pounds in educational technology (Ireland Ministry of Education and Science, 2001). The generous investments were supported by the strongly held premise that technology can help students learn more efficiently and effectively, and as a result increase student academic achievement. This belief in the connection between technology and student achievement is a theme commonly emphasised in mission statements of educational technology projects and arguments to support educational technology investment (Zhao & Conway, 2001). For example, the first US national educational technology plan claims, 'Properly used, technology increases students' learning opportunities, motivation, and achievement' (U.S. Department of Education, 1996, p. 10). The second plan assures that technology would 'enhance learning and improve student achievement for *all* students' (U.S. Department of Education, 2000, p. 4). The third plan further states that with new technologies, '10 years from now we could be looking at the greatest leap forward in achievement in the history of education. By any measure, the improvements will be dramatic' (U.S. Department of Education, p. 11).

However, this premise on the crucial role of technology in student achievement has not been substantially supported by empirical evidence. In fact, findings from different empirical studies focusing on the effect of technology on learning have been inconsistent and contradictory. On the one hand, some studies have identified significant positive impact of technology use on student outcomes in academic areas such as literacy development (Blasewitz & Taylor, 1999; Tracey & Young, 2006), reading comprehension and vocabulary (Scrase, 1998; Stone, 1996; Woehler, 1994), writing (Nix, 1998), mathematics (Elliott & Hall, 1997; Mac Iver, Balfanz & Plank, 1999) and science (Harmer & Cates, 2007; Lazarowitz & Huppert, 1993; Liu, Hsieh, Cho & Schallert, 2006; Reid-Griffin, 2003). For example, Tienken and Wilson (2007) compared seventh-grade students whose teachers used mathematics websites and presentation software in their classrooms with students whose teachers did not teach with these technology tools. They found that the use of these technology tools had a positive effect on students' learning of basic mathematic skills. In addition, positive impacts have been identified in student developmental areas, including attitude towards learning and self-esteem (Nguyen, Hsieh & Allen, 2006; Sivin-Kachala & Bialo, 2000), motivation, attendance and discipline (eg, Matthew, 1997). For example, using a mixed-method design, Wighting (2006) reported that using computers in the classroom positively affected students' sense of learning in a community. Similarly, in the UK, a series of research studies have been conducted to examine the effect of the large-scale Tablet PC programmes, and findings reveal that the use of technology has improved student access to curriculum, communication and motivation (eg, Sheehy *et al*, 2005; Twining *et al*, 2006).

On the other hand, several other researchers have come to very different conclusions. Some argue that technology use may not have any positive impact on student outcomes. For example, The Organization for Economic Co-operation and Development's (OECD) Programme for International Student Assessment 2003 study found that stu-

dents using computers most frequently at school did not necessarily perform better than students using technology less frequently, and the impact of technology use on student math achievement varied by countries (OECD, 2005). In March 2007, the Institute of Education Sciences released an influential report titled *Effectiveness of Reading and Mathematics Software Products: Findings from the First Student Cohort*. This study, intended to assess the effects of 16 computer software products designed to teach first- and fourth-grade reading and sixth-grade math, using a rigorous random assignment design, found that 'test scores in treatment classrooms that were randomly assigned to use products did not differ from test scores in control classrooms by statistically significant margins' (Dynarski *et al*, 2007, p. xiii).

Furthermore, some studies suggest that technology use might even harm children and their learning (eg, Healy, 1998; Stoll, 1999). For example, Waight and Abd-El-Khalick (2007) found that the use of computer technology restricted rather than promoted 'inquiry' in a sixth-grade science classroom. Mixed findings have also emerged from large-scale international studies. A study of the Trends in International Mathematics and Science Study (TIMSS) reported that technology use was negatively related to science achievement among eighth graders in Turkey (Aypay, Erdogan & Sozer, 2007). Another TIMSS study found that while medium use of computer technology was related to higher science scores, extensive use was related to lower science scores (Antonijevic, 2007). Similarly, based on data collected from 175 000 15-year-old students in 31 countries, researchers at the University of Munich announced that performance in math and reading had suffered significantly among students who had more than one computer at home (MacDonald, 2004). Schacter (1999) also identified some negative impacts on student achievement through the review of five large-scale studies that employed diverse research methods to examine the impact of educational technology. Discouraged by these findings, some people have come to the conclusion that putting computers in classrooms has been wasteful and pointless (Oppenheimer, 2003).

Existing research on the relationship technology on student learning presents a mixed message (Andrews *et al*, 2007; O'Dwyer, Russell, Bebell & Tucker-Seeley, 2005; Torgerson & Zhu, 2003). Such mixed and often conflicting findings make it difficult to draw conclusions about the effects of technology, to provide meaningful advice to those who make decisions about technology investment in education and to make practical suggestions for integrating technology into schools.

There are at least two problems contributing to the controversy over the relationship between technology use and student outcomes. The first is that technology is often examined at a very general level (Zhao, 2003). Many studies 'treat technology as an undifferentiated characteristic of schools and classrooms. No distinction is made between different types of technology programs' (Wenglinsky, 1998, p. 3). We know that technology is a very broad term that includes many kinds of hardware and software. These technologies may have different impacts on student outcomes. Even the same technology can be used differently in various contexts to solve all kinds of problems (Zhao) and thus have 'different meanings in different settings' (Peyton & Bruce,

1993, p. 10). Treating technology as if it is a single thing obscures the unique characteristics of different technologies and their uses.

The second problem is the focus of the studies. Most studies focus on the impact of the quantity of technology use, in other words, *how much* or how frequently technology is used, but ignore the quality of technology use, that is, *how* technology is used. For example, many studies examine the relationship between how much time students spend on using computers or how often they use computers and their achievement (eg, Du, Havard, Yu & Adams, 2004; Mann, Shakeshaft, Becker & Kottkamp, 1999). However, research suggests that the quality of technology use is more critical to student outcomes than the quantity (Burbules & Callister, 2000; Lei & Zhao, 2007; McFarlane, 1997). As Goldenberg (2000) pointed out that 'what really matters is not the use of technology, but how it is used' (p. 2). Thus, the necessary next step is to examine how different uses of diverse technologies affect student learning.

This study investigates the relationship between technology use and student outcomes by comparing the association between the quantity of technology and student outcomes with the association between the quality of technology use and student outcomes. This approach differs from many previous studies in at least two aspects. First, it studies technology at a more specific level instead of technology in general. Second, to better discern the quality of technology use, this study focuses on different uses of technology rather than on specific technological objects such as hardware or software. 'Technology use' is the application of a technology function to solve practical problems (Zhao, 2003). The focus is technology-in-context. Examining technologies from this angle allows us to discern the different uses of the same technologies so that the nature of different technology uses can be better understood.

Analytical framework
Technology use
In this study, both the quantity and the quality of technology use were examined. The quantity of technology use was measured by the time spent on computers everyday. The quality of technology use was examined by looking at how technology was used. Based on the natural impulses of a child proposed by John Dewey (Dewey, 1943): inquiry, communication, construction and expression, Bruce and Levin (1997; Levin & Bruce, 2001) proposed a taxonomy of technology for learning: media for inquiry, media for communication, media for construction and media for expression. Based upon, and modified from, this taxonomy of educational technology, technology uses in this study were broken down into the following categories based on the function of technology use: (1) subject-specific technology uses, which included technology uses for specific subjects; (2) social-communication technology uses, which included technology uses for social and communication purposes; (3) construction technology uses, which included technology uses for specific; (4) exploration/entertainment technology uses, which included technology uses for entertainment and self-exploration; and (5) general

technology uses, which included technology uses for general purposes. A more detailed explanation is provided later in this paper in the methods section.

Student outcomes
The following student outcomes were examined in this study: student academic achievement, technology proficiency, improved learning habits and developmental outcomes.

Student academic achievement

One of the fundamental reasons schools spent time and money on integrating technology was to improve student academic achievement (U.S. Department of Education, 1996, 2000). Therefore, the relationship between technology use and student academic performance was one of the major criterions for this study and was measured by student accumulative grade point average (GPA).

Technology proficiency

A second criterion focused on students' technology proficiency, because one of the chief goals of integrating technology into the classroom was to help students improve 'the mastery and application of new technologies' (U.S. Department of Education, 2004, p. 6). For example, students receive instruction in using a computer in order to become computer literate. Preparing students so that they can participate fully in our increasingly technological society continues to be a priority for many countries (eg, Singapore Ministry of Education, 1997, 2002; South Korea Ministry of Education and Human Resources Development, 2001; U.S. Department of Education, 2000). Therefore, technology proficiency was included as an important outcome.

Learning habits

Learning habits, or studying habits, are 'a set of behaviors related to how students organize their time and space to promote systematic study behavior' (Christensen, Massey & Isaacs, 1991, p. 292). Researchers have studied the importance of learning habits in teaching and learning, and the roles technology plays in enhancing those learning habits (Leamnson, 1999). Butler and Cartier (2004) argue that to be successful in an academic arena, students must adopt a work habit that can help them to carefully interpret the requirements of learning tasks. Bennett and Diener's (1997) study suggests that proper use of technology can help students enhance their learning habits. Therefore, this study included student learning habits as a third criterion.

Developmental outcomes

Middle school time is a very important period in the development of young people. Researchers have explored the connection between technology activities and the development of aspects such as self-esteem, life skills and positive attitudes towards schooling (Zhao, Tan, Lei, Shi & Martineau, 2003). Therefore, the fourth criterion for the study examined how technology could provide a variety of developmental experiences for children and youth, and may provide them with the opportunity for self-exploration.

Table 1 summarises the types of technology uses and student outcomes investigated in this study.

Table 1: Technology uses and student outcomes

	Student technology uses	Student outcomes
Quantity	Time spent on computers	
Quality	General technology uses	Academic achievement
	Subject-specific technology uses	Technology proficiency
	Social-communication technology uses	Learning habits
	Construction technology uses	Developmental outcomes
	Exploration/entertainment technology uses	

Methods

Participants were seventh- and eighth-grade students and teachers in a north-western middle school in the US. This was a comparatively small school, with a total enrolment of 237 for two grades, and the student–teacher ratio was 9.1 (2003–04 school year). This school had rich technology resources such as one-to-one laptops. Data were collected through surveys and interviews. Student GPAs were collected from their school records.

Survey

The survey was administered twice, at the beginning and at the end of the academic year. It included four sections. The first section asked about demographic information, including SES (socioeconomic status), grade and gender. The second section measured students' information technology proficiency. Based on existing literature focusing on student technology standards (eg, American Association of School Librarians & Association for Educational Communications Technology, 1998; Committee on Information Technology Literacy & National Research Council, 1999), the technology proficiency scale was developed to evaluate students' information technology proficiency. This scale presented participants 18 situation-based questions. Each question described a specific technology situation and then asked students to solve a practical problem by working on a multiple-choice question in each situation. The third section, student outcomes, included learning habits and developmental outcomes. Developmental outcomes included self-esteem, attitude towards schooling, and social skills. Questions in this section were Likert-scale questions measured on a scale of 1–5, with 1 indicating *strongly disagree* and 5 indicating *strongly agree*. Based on data collected from interviews, the fourth section, technology usage, listed 28 specific technology uses ranging from emailing and using PowerPoint for presentation to playing games and creating websites. Participants were asked to rate how often they worked with each of these technology uses. Academic achievement information (GPA) was collected from student report cards.

The survey was administered to all 237 students in this school. Among them, 207 students returned the first survey, 208 students returned the second survey and 177 students filled out both surveys. Data from students with more than one-third of all responses missing were deleted ($n = 34$), and data from special education students were deleted ($n = 10$) because the only technologies they used were assistive technologies, which were not included in this study. Therefore, altogether, 133 students' data were retained for final data analysis. Of the 133 students, 64 (48%) were male and 69 (52%) were female, and 64 (48%) were seventh graders and 69 (52%) were eighth graders.

Interview
To obtain an in-depth understanding of how technology was used, for what purpose(s), and in what contexts, we interviewed nine teachers and nine students. The fundamental selection criterion of interviewees was to have them represent the school population as much as possible. The selection of teachers for interview was based on the grade and subject they taught. As this was a comparatively small school, generally speaking, there was one teacher for one subject in each grade. The nine teachers included two math teachers, two science teachers, two social studies teachers, one language arts teacher, one technology specialist and one technology teacher. Five of these teachers were male and four were female. The students were selected based on their level of interest in using technology: two students greatly liked technology, one student did not like technology and the others were somewhere in between. They were also asked for their perspectives on the impact of technology uses on learning. All participants were interviewed individually, and each interview lasted for 25–30 minutes. For data-coding purposes, all interviews were audiorecorded with consent and/or assent.

Data analysis
Reliability check
Reliability was checked for researcher-designed scales. The reliability of the student technology proficiency scale, learning habit scale and developmental outcome scale was 0.77, 0.77 and 0.90 respectively.

Categorizing technology use
The 28 specific technology uses in section four of the survey were categorised into five groups according to the purposes and nature of use. Subject-specific technology uses included technology uses related to subject content, such as learning with the ALEKS (an online math programme) for math and learning with Geometer's Sketchpad for geometry. Social/communication technology uses included technology usage for communication or social interaction purposes, such as emailing teachers, emailing friends and chatting online with friends. Construction technology uses included technology uses that create products, such as creating websites and editing pictures. Entertainment/exploration technology uses included technology uses for fun and self-interest, such as playing games and exploring with new technology. General technology uses included technology that can be applied to any content area and for any purpose, such as taking notes and searching the Internet for information.

Linear regression analyses were conducted to examine the relationships between technology uses and student outcomes. Interview data were coded and analysed according to specific research questions.

Results

This section first examines the relationship between the quantity of technology use—how much time was spent on computers—and student outcomes, and then examines the relationship between the quality of technology use—how technology was used—and student outcomes.

The quantity of technology use and student outcomes
Time spent on computers everyday
Descriptive analysis results revealed that, as shown in Table 2, 32.3% of the students spent less than 2 hours a day on computers, 30.8% of the students spent about 2–3 hours a day on computers and 36.9% of them spent more than 3 hours a day on computers.

The relationship between the quantity of technology use and student outcomes
To examine the relationship between the quantity of technology use and student outcomes, we conducted regression analysis to analyse how the time spent on computers affects each of the four student outcomes: GPA, technology proficiency, learning habits and developmental outcomes.

Table 3 shows that this regression model explained only 3.1% of the total variation. Table 4 shows that how much time spent on computers everyday was not significantly associated with student GPA ($p = 0.12$). In other words, no strong association was identified between the quantity of technology use and student GPA.

Table 2: Time spent on computers

Time	Percent of students
Less than 1 hour	7.7
About 1–2 hours	24.6
About 2–3 hours	30.8
More than 3 hours	36.9

Table 3: Model summary

Model	R	R square	Adjusted R square	Standard error of the estimate
1	0.177	0.031	0.016	0.39748

Table 4: *Relationship between the quantity of technology use and student grade point average*

	B	Standard error	t	p
(Constant)	0.279	0.177	1.58	0.120
How much time do you spend on computers everyday?	−0.074	0.052	−1.41	0.164

Table 5: *Relationsihp between technology uses and student grade point average*

	Regression coefficient				
Effect	β	SE (β)	Effect size	t	p
(Constant)	5.735	2.243		2.56	0.012
General technology use	0.092	0.159	0.10	0.58	0.565
Subject-specific technology use	0.023	0.103	0.04	0.22	0.828
Social-communication technology use	0.120	0.099	0.21	1.21	0.230
Construction technology use	0.002	0.098	0.00	0.02	0.982
Entertain/explore technology use	−0.129	0.095	−0.24	−1.36	0.177

SE, standard error.

Similarly, regression analyses revealed nonsignificant relationship between the quantity of technology use and student technology proficiency ($R^2 = 0.01$, $B = 0.2$, $p = 0.27$), learning habits ($R^2 = 0.01$, $B = 0.06$, $p = 0.26$) and developmental outcomes ($R^2 = 0.01$, $B = 0.08$, $p = 0.20$).

In summary, when only looking at the quantity of technology use, data analyses revealed no significant relationship between technology use and student outcomes.

The quality of technology use and its relationship with student outcomes
This section examines the relationship between technology use and student outcomes from another angle: the quality of technology use, that is, how technology was being used. Specifically, regression analyses were conducted to examine if students' outcomes were affected by the five types of technology uses: general technology use, subject-specific technology use, social-communication technology use, construction technology use and entertainment/exploration technology use.

Relationship between different technology uses and student academic achievement
Table 5 presents the results of regression analysis on the relationship between different technology uses and student academic achievement, as represented by student GPA. Effect sizes are also included to show the strength of the relationship.

As shown in Table 5, using technology for social-communication purposes had some positive influence on student GPA. Although this influence was not statistically signifi-

cant, an effect size of 0.21 on GPA was noteworthy compared with a possible 0.33–0.50 effect size gain on student performance based on 'everything that happens to a student' (Kane, 2004, p. 3) across one academic year. This association was probably the result of students using social-communication technologies to communicate with teachers regarding assignments and questions on lectures. With these means of communication, students could receive responses more quickly than with traditional methods. Social-communication technologies also provided students more opportunities and avenues to ask questions. A number of teachers mentioned that they often received email messages from students who were too shy to ask questions in the classroom. Students also mentioned emailing their teachers during the interviews. They reported that it was easier and more convenient to ask questions or set appointments with teachers through email. For example, one student said she was able to 'talk to them (teachers) a lot more. If you have a question, even if you are at home, you can e-mail them and ask them. You don't have to wait until class to ask. By then you may have already forgot. I can get a response pretty quick'. Another student also reported that it was easier to email teachers to ask questions because 'we don't have to go and find that specific person'.

Entertainment-exploration technology uses were negatively associated with student GPA (ES (Effect Size) = −0.24, $p > 0.05$). This was likely the result of using study time for entertainment. The more time spent on these technology uses, the less time left for learning. In the interview, students talked about 'other students' who spent too much time playing computer games and commented that that was not good for their learning.

It should be acknowledged, however, that the relationships between student GPA and technology uses identified in this study were not necessarily causal but associative in nature. This applies to other relationships identified through regression analysis in this study.

Relationship between technology uses and student technology proficiency
A regression analysis was conducted to examine the relationship between different technology uses and student technology proficiency. As shown in the following two tables, this regression model was statistically significant ($p < 0.05$), and it explained 14.3% of the total variation (Table 6).

As shown in Table 7, general technology use had a marginally significant influence on student technology proficiency ($t = 1.83$, $p = 0.07$) while subject-specific technology

Table 6: Model summary

Model	R	R square	Adjusted R square	Standard error of the estimate
1	0.378	0.143	0.098	2.94848

Table 7: Relationship between technology use and student technology proficiency

| | Regression coefficient | | | | |
Effect	β	SE (β)	Effect size	t	p
(Constant)	8.051	1.995		4.036	0.000
General technology use	1.416	0.774	0.32	1.829	0.071
Subject-specific technology use	−1.291	0.533	−0.43	−2.422	0.017
Social-communication technology use	−0.280	0.504	−0.10	−0.555	0.580
Construction technology use	−0.596	0.495	−0.21	−1.206	0.231
Entertain/Explore technology use	0.322	0.449	0.13	0.718	0.474

SE, standard error.

use had a significantly negative influence on student technology proficiency ($t = -2.42$, $p < 0.05$). This is understandable in that when using more general technologies, the tasks are not certain, the technologies vary and students often have to explore new features of certain technologies, thus, they have the opportunity to learn more about technology. However, when they use subject-specific technologies to learn, the tasks are focused on specific subject content and the procedures to accomplish the tasks are generally similar. Therefore, once students know how to follow these procedures, there are no more technological challenges and no opportunities to expand technology knowledge and skills.

Relationship between technology uses and student outcomes
The relationship between technology use, and student learning habits and developmental outcomes was also examined by using regression analysis. To better compare the relationships between different technology uses on different student outcomes, the overall findings were summarized in Table 8.

Table 8: Relationships between technology uses on student outcomes (effect size)

Student outcomes	GPA	Technology proficiency	Learning habits	Developmental outcomes
Student technology uses				
General technology use	0.10	0.32	0.11	−0.03
Subject-specific technology use	0.04	−0.43*	0.04	−0.03
Social-communication technology use	0.21	−0.10	−0.09	0.35*
Construction technology use	0.00	−0.21	−0.16	0.00
Entertainment/exploration technology use	−0.24	0.13	0.51**	−0.08

*$p < 0.05$; **$p < 0.01$.
GPA, grade point average.

Table 8 lists the effect size of the regression coefficient of each technology use on every student outcome. Results in Table 8 show that different technology uses have different influences on specific student outcomes. General technology uses were positively associated with student technology proficiency, but the influence on other outcomes was minimal. Subject-specific technology use had a significantly negative association with student technology proficiency. In addition to the noticeable positive association with student academic achievement, social-communication technology use had a significantly positive influence on student developmental outcomes (ES = 0.35, $p < 0.05$). It is arguable that the more students used technology for social-communication purposes, the more they felt socially connected, a very important feeling for teenage students who need support from their peers and adults (Wighting, 2006). Being able to email and chat online also helped students to locate resources and find help when needed. As one student said, 'If you have a problem, you can ask your friends to help you online'.

Entertainment-exploration technology use significantly influenced student learning habits (ES = 0.51, $p < 0.01$). In the interview, students reported that entertaining activities and exploring with technology could help them organise their learning tasks better. For example, remembering and following rules in computer games may help students follow instructions in classrooms more efficiently, and ease in following directions should be beneficial to students' attaining learning outcomes. However, it seems this potential advantage was nullified or even outweighed by the consequences of spending too much time on entertainment-exploration technology use.

Limitations
This study had some practical limitations. First, this school had rich technology resources that were not available in many schools; thus, it was not a typical school that could represent most of the schools in the US. This weakness may limit the generalisability of the findings. However, as more and more schools are considering one-to-one computing initiatives (Lei, Conway & Zhao, 2008), this study provides a glimpse of where most schools will be in the near future. Second, the quantitative analyses were based on student self-reported data (such as time spent on laptops and types of activities). The validity of the self-reported data could not be verified. Third, data in this study were collected through one academic year, which might be too short a period of time for significant changes to happen. Longitudinal empirical research is needed to identify the association and long-term impact. In addition, some students in this study spent relatively small amount of time on computers everyday. This may have weakened the possible associations between technology use and student outcomes. Nevertheless, this study was able to reveal the differences in findings between examining the quantity of technology use and examining the quality of technology use.

Conclusions and implications
This study investigated the relationship between technology use and student outcomes by examining both the quantity of technology use, how much time was spent on computers, and the quality of technology use, how technology was used. When only examining how much time was spent on computers, no significant relationship was

found between technology use and any student outcomes. However, when how technology was used was examined, significant association was identified between technology use and most student outcomes. General technology use helped improve student technology proficiency while subject-specific technology use significantly impeded the development of technology proficiency. Social-communication technology uses had a significant positive association with student developmental outcomes and a moderate positive association with student academic achievement. Furthermore, the same type of technology uses had different influences on different student outcomes. For example, entertainment-exploration technology uses helped improve student learning habits. However, it might affect student academic achievement if too much time is spent on using technology for entertainment.

The fact that none of these five types of technology uses had statistically significant effects on student GPA suggests that we should be realistic about the influence of technology use on student outcomes. This might be disappointing to some people in that a major argument and goal for integrating technology in schools have been to improve student achievement, as discussed at the beginning of this paper. However, this does not mean that technology does not affect student learning. In this study, student technology uses were divided into five categories, which probably were still too general to differentiate the effects of different specific technology uses. Each category had several specific technology uses. If the specific technology uses within the same type had different associations with student outcomes, then their effects might have cancelled out each other.

The validity of the measurement of academic achievement can also be an issue. Student academic achievement was measured by traditional assessment methods, which were not likely to be an accurate assessment of student learning with, and about, technology. Although students used various technologies to work on problem-based projects by searching information online, videotaping interviews, creating PowerPoint presentations and designing websites. These activities were very different from a traditional activity such as listening to, and taking notes from, lectures. However, the examinations were not different from those of previous years. As a teacher pointed out, student learning with technology was difficult to measure because much of this kind of learning was hidden. Students now had opportunities and resources to explore far beyond the borders of the conventional classroom. One teacher commented, 'I don't think we have a way to evaluate it yet, or we don't ask the right questions to find out what they did'.

Findings from this study have significant implications for policy-making, research and practices regarding technology integration in schools.

Focusing on the quality of technology use
Results from this study suggest that technology can have significant influence on student outcomes, but the influence depends not only on how the technology was used but also on how the influence was examined and measured. This calls for more empha-

sis on the quality of technology use in both research and practices. The access to technology has been dramatically increased in the last two decades. However, for technology to have meaningful impact on teaching and learning, close attention must be paid on the quality of technology use: how is it being used, what is used and for what purposes.

Be realistic about the impact of technology
Results from this study show that student academic outcome (GPA) may not be easily improved through the use of technology. This is probably because student performance, especially academic outcomes measured by GPA, is influenced by many factors. Technology usage is just one of these factors. The association between technology use and student outcomes is not determined merely by the particular technology uses but is mediated by environmental factors, the users, the technology, and the constantly changing interactions and mutual influences. Therefore, it may be unrealistic to expect dramatic changes in student performance through one or two specific technology uses.

Set specific educational goals for technology use
Because different technology uses have different influences on student outcomes, to facilitate technology use in schools and to accurately assess the effectiveness of specific technology uses, it is important to set clear educational goals even before technologies are purchased and installed. It has been pointed out that schools have often been uncertain about the outcomes they want to achieve with technology (Protheroe, 2005), and this uncertainty can and probably often result in a waste of money, inappropriate purchase and teacher preparation in the process of technology integration. The decision makers need to ask these questions: what do students need to learn? what abilities do students need to develop? What daily tasks do teachers need to perform? how can technologies help achieve these goals and accomplish these tasks? Based on this information, clear educational goals and expectations can be set for specific technology uses. Then teachers and students would be provided with a clear understanding of the purposes for technology use, and the impact of technology use could be assessed in more meaningful and practical ways.

Suggestions for future research
Additional research needs to be conducted along the following lines. First, identify more effective technology uses. Technology has the potential to improve teaching and learning. However, for this potential to be realised, it must be 'properly used'. More research on effective technology usage is required to help policy-makers, educators and practitioners understand what technology uses are 'proper use' of technology so that the potential benefits of technology can be reaped by teachers and students alike. Second, the effectiveness of technology use is contingent on the specific student outcomes. Academic achievement should not be the only criterion for evaluating the meaningfulness or effectiveness of technology use. Some other outcomes are also important components of school education, including student behavior, attitude, self-esteem, digital literacy and career aspiration. Exploration of these aspects can help enhance the effectiveness of using technology to help develop complete learners. Third, there is a need to

explore and develop evaluation methods and instruments that evaluate student learning with technology. Student technology use and learning is experience-related and at times hidden or subtle; consequently, it cannot be assessed through traditional outcome evaluation. Some alternative assessment methods such as performance assessment, essays and portfolios might be more effective in assessing student learning with, and about, technology. Fourth, this study examined the quality of technology use by looking at five types of technology use. This categorisation was helpful in this study to reveal the critical difference between the quantity and the quality of technology use, but it also had some limitations. For example, as each type of technology uses consisted of several specific technology uses, the grouping might have cancelled out the differences among these specific technology uses. Research needs to further explore effective ways to measure the quality of technology use.

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