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Information and Communication Technologies (ICT) in an Elementary School: Students' Engagement in Higher Order Thinking

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Based on a case study of an elementary school in Singapore, this article describes and analyzes how different types of ICT tools (informative, situating, constructive, and communicative tools) are used to engage students in higher-order thinking. The discussion emphasizes that the objective of the lesson and the orienting activities, rather than the ICT tools, play an important role in engaging students in higher-order thinking. Different types of ICT tools are often used to complement one another to achieve the lesson objectives. However, the classification of an ICT tool is based more on how it is used than its characteristics. Just-in-time ICT skills training facilitates the students in their learning process. Moreover, effective management of digital instructional resources that ensure seamless and easy retrieval supports the integration of ICT into the curriculum.

In the last two decades, research studies of information and communication technologies (ICT) in education have shifted away from the analytic study of single learning and instructional variables towards the whole configuration of events, activities, contents, and interpersonal processes taking

place in the context that ICT is used (Fontana, Dede, White, & Cates, 1993; Herrington & Oliver, 1998; Jonassen, Peck, & Wilson, 1999; Sarapuu & Adojaan, 1999; Oliver & Hannafin, 2000; Jonassen, 2000; Jonassen & Carr, 2000; Hollingworth & McLoughlin, 2001; Kearney & Treagust, 2001; Neo & Neo, 2001). These studies have shown that ICT, like any tools in the learning environment, may be used well or poorly, and care and experience are needed when using it.

Based on a case study of an elementary school in Singapore, this article describes and analyzes how different types of ICT tools are used to engage students in higher-order thinking. The four types of ICT tools discussed are informative, situating, constructive, and communicative tools. The case study rejects the view that ICT can be studied in isolation. Instead, it emphasizes on how ICT tools are studied within the context that they are situated. Altogether 15 observations of ICT-based lessons, 3 teacher interviews, and 3 focus group discussions with students were conducted in the collective case study.

The case study is one of the ten selected schools in a larger study that explores where and how ICT is situated in Singapore schools to engage students in higher-order thinking. The larger study consists of two phases: Phase One is a questionnaire survey aimed at exploring the critical aspects of ICT integration among Singapore schools; and Phase Two is a collective case study of 10 schools (5 elementary schools, 3 high schools, and 2 senior high schools). They are chosen based on their high degree of ICT integration reported in Phase One. As of December 2002, all 368 schools in Singapore are equipped with the necessary hardware, software, and infrastructure that support an ICT integrated learning environment. Therefore, it is most appropriate to study where and how ICT is situated to engage students in higher-order thinking as the process of ICT integration in Singapore schools had reached a considerable level of maturity and stability.

TYPES OF ICT TOOLS AND HIGHER-ORDER THINKING

This section first defines higher-order thinking in order to facilitate the discussions of the different types of ICT tools. The literature reviewed focuses on how the different ICT tools are used to engage students in higher-order thinking.

Higher-Order Thinking

Gagne, Briggs, and Wager (1992) identified five categories of learning outcomes: (a) verbal information; (b) intellectual skills; (c) cognitive strategies; (d) attitudes; and (e) motor skills. Intellectual skills are further subdivided into five hierarchically ordered subcategories and they are: (a) discriminations; (b) concrete concepts; (c) defined concepts; (d) rules, and (e) higher-order rules—problem solving. Out of this list of learning outcomes, higher-order rules—problem solving and cognitive strategies are associated with higher-order thinking-type of learning outcomes. Higher-order rules represent combinations of simpler rules for the solving of complex problems. As for "cognitive strategies, they consist of numerous ways by which students guide their own learning, thinking, acting, and feeling" (Driscoll, 2000, p. 354).

Higher order thinking is more than the simple recall of facts or information retrieval. It is a function of interaction between cognitive strategies, meta-cognition, and nonstrategic (domain-specific) knowledge during novel problem solving (Young, 1997). Higher order thinking skills are then "goal-directed, multi-step, strategic processes such as designing, decision making, and problem solving" that require analyzing, evaluating, connecting, imagining, elaborating and synthesizing (Iowa Department of Education, 1989, p. 7). This definition of higher order thinking provides a platform for the discussion of ICT tools in this article.

Classification of the Different Types of ICT Tools

Depending on the instructional activities, ICT can play different mediating roles in the instructional process. The ICT tools can be classified into four categories: (a) informative tools, (b) situating tools, (c) constructive tools, and (d) communicative tools (Chen, Hsu, & Hung, 2000). Informative tools are applications that provide vast amounts of information in various formats such as text, sound, graphics, or video. Informative tools do not really "do" anything; rather they are considered as huge, passive, repositories of information. Examples of informative tools include multimedia encyclopedias or resources available on the World Wide Web (WWW or Web). Situating tools are systems that situate students in an environment where they may "experience" the context and happenings. Examples of such systems include simulation, games, and virtual reality.

Constructive tools are general-purpose tools that can be used for manipulating information, constructing one's own knowledge or visualizing one's

understanding. The term "constructive" stems from the fact that these tools enable students to produce a certain tangible product for a given instructional purpose. For example, web authoring applications allow students to create their own web pages and communicate their ideas to the world. Communicative tools are systems that mediate communication between the teacher and students or among students beyond the physical barrier (either by space, time, or both) of the classroom. Examples of communicative tools include e-mail, electronic bulletin boards, chat, teleconferencing, and electronic whiteboards.

ICT Tools Engaging Students in Higher Order Thinking

The discussion in this section is on how the different types of ICT tools engage students in higher-order thinking.

Informative tools. Fontana and colleagues (1993) experimented with the design of a multimedia prototype with rich multimedia databases to foster higher-order thinking skills in social studies. The researchers attempted to use the same technologies that swamped students with data to mediate students' mastery of the thinking skills for synthesizing information. The computer-based instructional system provided students with explicit instruction, guided inquiry, tutoring and coaching from teachers, collaborative learning with peers, and student controlled production. Such a system required a refocusing of the current uses of multimedia in the curriculum, from engines for transmitting massive amounts of data to tools for structured inquiry based on higher-order thinking.

The researchers suggested that higher-order thinking skills for structured inquiry were best acquired where: students constructed knowledge rather than passively ingest information; learning was situated in real-world contexts rather than based in artificial environments such as end-of-chapter textbook questions; sophisticated information-gathering tools were used to stimulate students to focus on testing hypotheses rather than on plotting data; multiple representations for knowledge were used to help tailor content to suit individual learning styles; there was collaborative interaction with peers; individualized instruction targeted teacher intervention to assist each student in solving current difficulties; and evaluation systems measured complex, higher-order skills rather than simple recall of facts (Fontana, Dede, White, & Cates, 1993).

Oliver and Hannafin (2000) investigated the use of computer tools to manage and manipulate Internet-based hypermedia resources by 12 middle

school students. The main purpose was to experiment how Internet resources could support student inquiry. Different types of ICT tools were used, from the searching for relevant materials to the presentation of the resources collected. The tools were proposed to support higher-order thinking about hypermedia resources to help students find, frame and resolve open-ended problems. Higher-order thinking represented efforts to process and understand information through organization, synthesis, reasoning, and evaluation. It was reported that tools alone were insufficient to help students to manage hypermedia information for solving open-ended problems. Students more frequently applied lower-order tool functions (e.g., information collection) than higher-order tool functions (e.g., reasoning). Students typically resolved problems with original solutions, but tools were infrequently used to develop evidence-based arguments justifying new ideas. Oliver and Hannafin (2000, p. 91) argued that:

> Students may benefit from training in strategic tool use or modeling of tool-enhanced problem solving, as well as specific activities or tool mechanisms to help them communicate and hypothesize about open-ended problems. That combination of scaffolding and tool support may help students to develop more advanced epistemological beliefs and to ultimately apply tools more strategically toward understanding and resolving complex, open-ended problems.

Therefore, informative tools alone may not be sufficient to help students manage extensive hypermedia resources. It is only together with appropriate support structures that the potential of informative tools for engaging students in higher-order thinking is more likely to be realized.

Situating tools. Hogle (1996) explored the use of computer games to increase interest, motivation, and retention, as well as to enhance higher-order thinking. He stated that simulation and games might improve several types of cognitive learning strategies that included organizational strategies (paying attention, self-evaluating, and self-encouragement), memory strategies (grouping, imaginary, and structured review), and compensatory strategies (guessing meaning intelligently). Successful play required extensive critical thinking and problem-solving skills. However, Hogle (1996) emphasized that the educational benefits of games depended on "the intended purpose of the game, and the context in which it is used" (p. 12).

Kearney and Treagust (2001) described the fruitful interaction between educational research on constructivism and the development and use of a multimedia computer program. The software used interactive digital video

clips to present 16 real world demonstrations to Physics students. A predict-observe-explain strategy was used to structure the students' engagement with the video clips and to promote students' conceptual development in the domain of Physics by one or more of the followings: articulation and/or justification of the student's own ideas; reflection on the viability of other students' idea; critical reflection on the student's own ideas; and construction and/or negotiation of new ideas. The authentic video demonstration plus the predict-observe-explain teaching strategy facilitated higher order thinking such as analyzing, evaluating, and connecting as students actively reorganized their knowledge.

Constructive tools. Jonassen and Carr (2000) discussed learning with technology from a constructivist perspective. They suggested that computers could be used as mindtools for the construction and facilitation of the learning of higher-order thinking skills. Mindtools included computer applications such as databases, spreadsheets, semantic networking programs, expert systems, modeling tools, microworlds, and hypermedia authoring tools that enable students to represent what they have learned by using different representational formalisms. Using mindtools to represent what they have learned engages students in a variety of higher order thinking, such as evaluating, analyzing, connecting, elaborating, synthesizing, imagining, designing, problem-solving, and decision-making. In this case, the role of ICT is not that of a teacher/expert, but of a mind-extending cognitive tool. Jonassen and Carr (2000) emphasized that the individuals who learned the most from intelligent tutors were the ones who build them, not the students who used them. They suggested that in order to maximize the learning of higher-order thinking, students should be actively involved in the construction of their own knowledge with the help of ICT tools.

Neo and Neo (2001) reported on how students became more analytical and critical thinkers, more apt to seek information, and more motivated in their learning using web-based multimedia authoring tools, Macromedia *Dreamweaver* and *Flash*. The course was structured for constructivist learning whereby students constructed their own knowledge of the project, determined their own learning outcomes, and worked in a collaborative and cooperative manner, thus taking an active part in the process. The students were required to reconstruct any existing website of their choice in the Internet that they thought required improvements. The purpose of the project was to assess problem solving skills and the ability to evaluate a website's design, creativity, and navigational structure. The students were required to enhance the site by adding sound and animation and improve the overall look and feel of the site using the computer tools mentioned earlier.

Students were first provided with skill-based training for the authoring tools and the fundamental concepts of the multimedia design process. When in doubt, students either made an appointment to see the lecturer or use the Internet to chat with the lecturer. At the end of the project, each group of students was required to give a brief presentation and also answer questions posed by the lecturer and their fellow classmates.

Communicative tools. Lapadat (2000) examined how students engaged in interactive online courses and used the discussion board as a tool for thinking and negotiating meaning. In particular, it investigated the idea that discursive interaction in asynchronous, text-based, online courses might be uniquely suited to fostering higher-order thinking, social construction of meaning, and shifts in perspective. The findings pointed to the unique potential of online discussion-based courses as learning environments. Lapadat (2000) stated "by reading and responding in writing to each other, class members defined matters of importance to them, posed and solved problems, and theorized about epistemology, practice, and policy" (p. 18). This interactive environment engaged participants towards an epistemic usage of text. Wells (1990) defined such epistemic engagement with written text as "a tentative and provisional attempt on the part of the writer to capture his or her current understanding in an external form so that it may provoke further attempts at understanding as the writer or some other reader interrogates the text in order to interpret its meaning" (p. 373). Such epistemic literacy yielded what Lapadat (2000) classified as higher-order thinking: analysis, synthesis, interpretation, and evaluation.

From the previous discussion, it is clear that an ICT tool by itself is neutral. The literature reviewed suggests that ICT can be a powerful and flexible tool for learning, but like any other tool, it requires care and experience to use appropriately. Hence, it is critical that research should not only explore the development of appropriate ICT to be used, but also explore the role of effective pedagogy that can maximize students' learning using ICT tools. This view is highlighted by Driscoll (2001):

> Technology should not be seen as computer hardware and software, but also as the processes involved in managing learning and the learning environment; the models used in designing, developing, and evaluating instruction; and the strategies implemented for improving human performance. (p. 336)

The main research question then is: How are the different types of ICT tools used to engage students in higher-order thinking? The sub-questions include:

- What are the processes involved in managing learning and the ICT-based learning environment?
- How are instructions designed, developed, and evaluated in the ICT-based learning environment?
- What are the strategies implemented to engage students in higher-order thinking with ICT tools?

RESEARCH DESIGN AND METHODS

A case study approach was adopted to explore how the ICT tools were used to engage students in higher-order thinking during ICT-based lessons. The most important criterion of using case study as a research method was to maximize what we could learn. It aimed to provide a "picture" of the phenomenon as it naturally occurred, as opposed to studying the impacts of the phenomenon or intervention (Merriam, 2001). The elementary school in this study was selected based on its high degree of ICT integration reported in Phase One of the main study, and was more likely to lead to a greater understanding of how ICT tools could be used to engage students in higher-order thinking. To understand and describe the processes involving teachers, students, and the ICT tools, qualitative research methods were employed. They included observations, focus group discussions, and interviews.

A constant theme that appears in the literature of case study research is triangulation, the use of multiple sources of evidence for data collection (Yin, 1994; Stake, 1995; Merriam, 2001). The most important advantage is the development of converging lines of inquiry where any finding or conclusion is likely to be more convincing and accurate if it is based on several different sources of information. With multiple approaches within a single study, we are likely to illuminate or nullify some extraneous influences (Yin, 1994; Stake, 1995). Therefore, in this case study, triangulation addressed the issues of validity and reliability.

Observations of ICT-Based Lessons

In the classic typology of naturalistic research roles, there are four modes through which observers may gather data. They are the complete participant, the participant-as-observer, the observer-as-participant, and the complete observer (Adler & Adler, 1994). Our role throughout the observation sessions was more towards the observer-as-participant and at times even

as a complete observer. Interactions with the teachers were mainly to introduce ourselves, and get more background information such as the teacher's years of experience and frequency of ICT usage. Interactions with students were restricted to only occasions when students requested for our help to resolve technical problems in the event that the teacher was busy with other students or when the technology assistant was not available. Other contacts with the students were mainly friendly greetings and exchange of brief personal information.

The observations allowed the gathering of rich data in natural settings. Rich data meant a better description and understanding of what went on in a particular context and improved the provision of clues and pointers to other layers of reality. An observation checklist was developed to guide the observation process. The items in the checklist include the layout of the room, lesson objectives, lesson sequence, types of ICT tools and non-ICT tools used, rules and procedures set, and roles of participants. Fifteen ICT-based lessons were observed in different subject areas: English, Mathematics, Science, Social Studies, and Music. Out of the 15 ICT-based lessons, eight were conducted in the computer laboratories and the remaining seven in the classroom.

Face-To-Face Interviews with Teachers

The interview was the main road to multiple realities in the case study. On some occasions, the researchers have to rely on what others have seen and done when observation was not possible. And on many other occasions, interview allowed the researchers to understand the observed teachers' actions (Stake, 1995). It also served to reconcile a common discrepancy between what the teachers said about themselves and what they actually did (Gillham, 2000); and hence, the interviews acted as a form of triangulation against what was observed from the teachers' perspective.

A total of three face-to-face interviews were conducted. The teachers were interviewed for approximately 45 minutes each. The interview questions were open-ended and the interviews were conducted in a conversational manner following a set of topics that provided some form of guiding structure. The topics covered included background information about the teacher, the different types of ICT tools used, the main objective of using ICT tools, the outcomes of ICT used, roles of the participants, and the rules formulated and enforced. The interviews allowed the teachers to express their thoughts and explain their behaviors or actions during the ICT-based

lessons observed. In addition, it allowed the researcher to be more in control and more focused on the research question as compared to the observations conducted. All interviews were tape-recorded and transcribed for the purpose of analysis.

Focus Group Interviews with Students

The focus group interviews were conducted with the students for three reasons: (a) they allowed for data collection from a group of students at a lower cost and faster than would be the case if each student were interviewed separately; (b) they allowed the researchers to interact directly with the students, hence providing opportunities for clarification and probing of responses; and (c) they allowed students to react to and build upon the responses of other group members.

The themes and questions for the focus group interviews were guided by the literature review and research question. Students from the upper primary levels were selected for the interviews because they were more articulate than the younger students. Three groups of six students each were chosen. For all the interviews, background information, context, and broader issues were discussed before the group focused on specific issues. The issues included their purpose and experiences of using ICT for learning, their access to ICT facilities, their roles during ICT-based lessons, and their perceptions of activities used during the ICT-based lessons. Notes were taken during the tape-recorded interviews to record both the nonverbal communications and other important points and issues.

Data Analysis

In this case study, data analysis within each method and between methods took place together with the data collection and data processing. The ongoing analyses helped to undo biases and errors that might have crept in the fieldwork and fine-tuned the research methods to reflect better understanding of the setting. The data collected was continually subjected to cross checking with the various sources of data. From the various sources of data, units of information were identified. In this research, these units became the basis for the emerging themes on the implications of how ICT tools were used to engage students in higher-order thinking.

FINDINGS

Background of the Case Study

The case study in Young Primary School, a government school, was carried out from July 3 to August 22, 2002. At the time of the study, the school was in its final phase of PRIME, a program for rebuilding and improving existing schools. Some minor works were still in progress and the lessons in the computer laboratories were disrupted for the first half of the year. There were about 1,800 students in the school, consisting of Chinese and Malay students from ages ranging from 7 to 12. The average class size was 36. The school had a staff strength of 70 teachers and 8 support staff. There were 3 computer laboratories; 21 computers each in two of the laboratories, and 15 computers in the third one. There was also a music laboratory with 15 computers.

All the classrooms were equipped with data projector, projector screen, whiteboard, and two to three computers. The computer that was located at the teacher's table was linked to the data projector. The other computers that were found in the classroom were for the students' use. A technology assistant (TA) was available in the school to provide technical support and resolve technical problems that might arise during the ICT-based lessons. The school had about 62 different CD-ROM titles. All these were housed in the school server and could be retrieved within the school's local area network through the Virtual Drive Network.

Table 1 presents an overview of the ICT-based lessons observed with respect to the lesson objective, different types of ICT tools used, time, and the venue where the lesson was conducted.

ICT Tools and the Engagement of Students in Higher-Order Thinking

For ICT lessons that were conducted in the classroom, they were mainly teacher directed with participation and discussion from the students. The lessons were delivered using the teacher's computer that was linked to the data projector. Different types of ICT tools were used for content or basic knowledge delivery with some attempts to engage students in higher-order type of thinking skills. For lessons that were conducted in the computer laboratories, students were given hands-on experiences with the computers at the ratio of 2 students to 1 computer.

Table 1
Overview of ICT-based lesson observations

No.	Lesson	Objective of ICT Lesson	Type of ICT tools used	Venue
1.	English Composition	Students were to write a narrative composition.	*Quest of Zenon* CD-ROM as a situating tool. Microsoft *PowerPoint* as an informative and constructive tool.	Class room
2.	Social Studies– Neighboring Countries	Students were to present to their classmates after conducting an inquiry using the Internet.	Internet as an informative tool. Microsoft *PowerPoint* as a constructive tool.	Class room
3.	Mathematics- Addition & Subtraction of Decimals	Students were to practice their addition and subtraction of decimals using the software programs.	Teacher created Mathematical practice game (using Macromedia Authorware). *Zarc Maths* 4B CD-ROM was used for drill and practice.	Computer Laboratory
4.	Science– Adaptation	Students were to present to their classmates after conducting an inquiry using the Internet.	Internet as an informative tool. Microsoft *PowerPoint* as a constructive tool.	Computer Laboratory
5.	Science– Adaptation	Students were to present to their classmates after conducting an inquiry using the CD-ROM title.	*Eyewitness Encyclopedia of Nature* 2.0 as an Informative tool. Microsoft *PowerPoint* as a constructive tool.	Computer Laboratory
6.	Mathematics - Addition & Subtraction of Decimals	Students were to practice the addition and subtraction of decimals.	*Zarc Maths* 4B CD-ROM was used for drill & practice.	Computer Laboratory
7.	Mathematics- Solving of Problem Sums	Students were to solve the problem sums given by the teacher.	Microsoft *PowerPoint* was used as an informative tool.	Classroom
8.	English Composition- Common grammatical errors	Students were able to recognize and check their own grammatical mistakes in their composition.	Microsoft *PowerPoint* as an informative tool. Microsoft *Word* as a constructive tool.	Computer Laboratory

(continued on next page)

Table 1 (continued)
Overview of ICT-based lesson observations

No.	Lesson	Objective of ICT Lesson	Type of ICT tools used	Venue
9.	Science-Simple Machines	Students were to revise the concept of Simple Machines.	*Tutor On Demand* CD-ROM as an informative tool.	Classroom
10.	Science–Pollution	Students were to search for relevant information for presentation	Microsoft *PowerPoint* as an informative and constructive tool. Internet as an informative tool.	Computer Laboratory
11.	Social Studies–Occupation	Students were to questions given in the computer software program and Social Studies Workbook. Students were to search for more information on Singapore's War Heroes in the Internet.	Teacher created software (using Macromedia Authorware) on the topic on Japanese Occupation. Internet as an informative tool.	Computer Laboratory
12.	Music–National Day Songs	Students were to practice with their recorders.	Microsoft *PowerPoint* as an information tool. (Presentation tool)	Music Laboratory
13.	Mathematics–Angles (Revision)	Students were to revise the concept of Angles.	*Zarc Maths* 5B CD-ROM as an informative tool.	Classroom
14.	English Composition Writing	Students were to write a composition.	Microsoft *PowerPoint* as an Informative tool. Microsoft *Word* a constructive tool.	Classroom
15.	Chinese Proverbs	Students were to recall and explain the meaning of the Chinese Proverbs.	Microsoft *PowerPoint* as an informative tool.	Classroom

The Virtual Drive Network was used to house all ICT teaching and learning resources including CD-ROMs and teacher-prepared presentation slides and software. This facilitated the use of ICT in teaching and learning by making the sharing and retrieval of the resources efficient. This was evident in many of the ICT lessons conducted in both the computer laboratories

and the classrooms. The Virtual Drive was mentioned in all the interview sessions with teachers and students. All the teachers shared their experiences of using the virtual drive and how they uploaded their materials and downloaded other teachers' materials. The icon for Virtual Drive was on all computer desktops in the school.

Informative tools. Both teachers and students used a number of informative tools. These tools included the Internet, CD-ROMs, and teacher-prepared *PowerPoint* presentation slides. From the classroom observations, there were several instances where informative tools were used to engage students in higher-order thinking. In one of the science lessons conducted in the computer laboratory, the teacher requested the students to search the Internet for the effects of pollution using the various search engines available. Before the students started on their search, the teacher presented (using *PowerPointto:*) a short list of concise and specific tasks that the students were required to accomplish. The students were also reminded verbally on the time given for the activity. In addition, the teacher emphasized that they should focus on the content rather than the overall design, sounds, and animations. At the end of the lesson, students were required to present their findings in a *PowerPoint* presentation with images and texts. The teacher shared her objective of the lesson during the interview session:

> …that type of lesson is more for information gathering, to let the child decide which information is more important. Not just to surf the net and then copy the whole chunk. That's why I, remember I said to do it in point form. So hopefully you know how to narrow down. I mean, the children should distinguish what content is necessary and what is not. There is a lot of information out there. That is the lesson I have in mind.

The students were required not only to search but also to evaluate, analyze, connect, synthesize, design, and present the information collected from their Internet search. In this instance, the students were taught Internet searching skills, specifically on how to narrow down their search results at the beginning of the year. The teacher shared that there was a lot of good information in the Internet and to locate them, Internet search skills were essential. During the focus group interview and lesson observation, the students revealed that their teacher taught them the Internet search skills. When the students were asked for their preference for the type of ICT-based lesson, they unanimously preferred the Internet because information was readily and easily available. They also felt that they could learn more from the Internet.

In another science lesson that was conducted in the computer laboratory, the students were instructed to jot down notes on the habitats of the animals and plants that were found in the CD-ROM titled *Eyewitness Encyclopedia of Nature 2.0*. The CD-ROM played the role of an informative tool, just like the Internet. The teacher demonstrated how to navigate the software and informed the students that at the end of the lesson, they were required to share their findings with their classmates using *PowerPoint*. The teacher provided just-in-time skill of toggling between the *Eyewitness Encyclopedia* and *PowerPoint* so that the students could create their *PowerPoint* presentation and refer to the content in the CD-ROM simultaneously. In addition, he also taught the students how to use design template provided by *PowerPoint*. In this lesson, the students were involved in analyzing, evaluating, and connecting the information that was collected from the CD-ROM. These were then consolidated and presented to the class on *PowerPoint* slides. The objective of the lesson was quite similar to the lesson on the effects of pollution, that is, to search, evaluate, analyze, and present the information found. However, instead of searching on the Internet, students were required to retrieve the information from the *Eyewitness Encyclopedia* CD-ROM.

During the focus group interview, students expressed that although they generally preferred the Internet, the CD-ROMs could also provide them with the required information without going through the hassle of searching the Internet, which at times, was futile. There were occasions where they could not locate the necessary information due to a lack of time and limited Internet searching skills. Students were aware of both the advantages and shortcomings of using the Internet. They reflected that more information could be gathered from the Internet as compared to the CD-ROM. According to the students, CD-ROM was an alternative source of information, just like the books found in the library. Two students perceived the *Eyewitness Encyclopedia*-typed of CD-ROMs as more of "an electronic book."

In an English composition lesson that was conducted in the classroom, the teacher showed a *PowerPoint* presentation that she retrieved from her personal folder in the school computer network system. With the *PowerPoint* presentation, a scenario entitled "Airport Misadventure" was presented to the students, followed by a number of questions. The scenario provided the setting and the questions acted as a catalyst to engage students in decision making, problem-solving, elaborating, imagining, and connecting. After the classroom discussion, the students were required to write a composition on another topic. Ideas and possibilities were generated through the teacher-students and students-students interactions during the class discussion. Activity sheets were designed to help students focus on the different

parts of the composition, namely the setting, problem, solution, and closure. In pairs, the students were required to complete the worksheet and share it with their classmates. The students were informed that they would be required to type out their composition using the word processing application in the computer laboratory in the following week.

Among the different types of ICT tools used, the informative tools were the most frequently used ICT tools for the purpose of providing basic and content knowledge that formed the basis for engaging in higher-order thinking skills. For most lessons observed, CD-ROMs and teacher-prepared *PowerPoint* presentations were used to facilitate the learning of basic content knowledge. The readily available computer, data projector, and projector screen that were found in every classroom facilitated the use of ICT in the classrooms. In addition, the ease of retrieving the required teaching resources from the school computer networking system had made the use of ICT in the classrooms much easier. After her lesson in the music laboratory, a music teacher demonstrated how easy it was to retrieve any teaching resources available in the virtual drive.

The teachers used the informative tools differently, according to the purpose of their lessons; that is, the same tool was used differently for different purposes. For example, the *PowerPoint* software was used for the presentation of information in many of the instances mentioned in this section. It was also used for the purpose of creating scenarios to stimulate students' creative thinking for composition writing. Students also used the same software to construct what they had learned from the Internet and the CD-ROM in their Science lessons.

Situating tools. A situating tool was used in one of the English composition lessons conducted in the classroom. A virtual reality program was used to create scenarios for creative and imaginative composition writing. In the lesson, the teacher used the CD-ROM entitled *Quest for Zenon* to create four to five scenarios with different types of vivid characters and elicit responses from the students for discussion. Through the class discussion, the teacher engaged the students in imagining, elaborating, and synthesizing the ideas generated. After the discussion, the students were asked to complete the following story: "The moment we stepped in, I knew we had made the biggest mistake in our lives." In addition, the teacher used the CD-ROM to generate 30 phrases to help the students in their composition writing. Students were required to write their composition using the writing pad and submit to their teacher.

Constructive tools. The most frequently used constructive tools by the students were *PowerPoint* and *Word*. These were used by the students for their presentation and composition writing, respectively. The data loggers and its accompanying software were used in the Science lessons. *Publisher*, *Photoshop*, digital camera, and other web page design tools were also used by some of the students who were involved in special projects and competitions.

PowerPoint was not used as an independent tool but as part of the lesson. When it was used in the Science and Social Studies lessons, students were given a topic to research on the Internet, textbooks, or CD-ROMs. They were later required to consolidate and present their findings using *PowerPoint*. Students who were interviewed said that they had to organize the relevant information collected and present it to their classmates.

As an introductory lesson to an English composition lesson, the teacher requested a student to prepare and present a *PowerPoint* presentation entitled "Why must we speak good English?" The presentation was about the importance of using and speaking grammatically correct English. The student had done a simple research on the above topic, organized and disseminated her findings through a *PowerPoint* presentation. The lesson ended with a grammar multiple-choice quiz for the whole class. The students in the class participated actively.

A teacher recalled during the interview how she demonstrated the data logger and its accompanying software to her students before a Science lesson. She carried out an experiment with the class on how well light was transmitted through paper of different density—transparent, translucent, and opaque. The data collected was used to plot three different graphs using the data logger software. The data loggers and its accompanying software were used to collect, compare, and measure light density. The teacher's main intent was to introduce the tool to the students and then give them hands-on experience to carry out other experiments and construct their own knowledge of scientific concepts based on the data collected. The teacher emphasized that she had to work through the experiment by herself before the class to ensure that she was familiar with the features of the tools and the procedures of the experiment.

One teacher shared her experiences of working with the school's News Team. The News Team was made up of a few teachers and a small group of students from primary 4, 5, and 6. The team would cover major schools events like Sports Day, Teachers' Day, National Day, Racial Harmony Day, to name a few. At year-end, the team would publish a newsletter using various constructive tools such as *Publisher* and *Photoshop*. Visits by special

guests were covered in the school's hot news. Hot news would be published and laminated, and then presented to the guests at the end of their visits. The News Team members were given authentic tasks to accomplish and this inevitably engaged the students in higher-order thinking. The students had to synthesize the information they had gather, imagine, and design for the production of the news. This also reinforced the idea that the use of ICT to mediate students' thinking process was not confined to classroom practices.

Teachers who were interviewed also shared their experiences of the two competitions that their students participated—Singapore ThinkQuest Junior Competition and the National Junior Robotics Competition. Singapore ThinkQuest Junior Competition required the students to research a topic of interest and present their findings in the form of a website. Webpage design, image editing, and animation software titles were used for the creation of the website. The National Junior Robotics Competition organized by the Singapore Science Center required the students construct their own robots using the *LEGO Mindstorm* and complete several missions stipulated by the organizer of the competition on the playing field.

Communicative tools. The use of communicative tools was not observed in any of the ICT-based lessons. Students interviewed expressed that they used communicative tools such as the e-mail occasionally for leisure purposes. But, the use of such tools for teaching and learning in school was not prevalent. In one of the interview sessions, one teacher commented that e-mail was used in an e-mail-mentoring project initiated by Hewlett Packard (HP) for the purpose of learning. The teacher recounted the process of the project: "They learn how to e-mail. First, is to subscribe to e-mailing system and they e-mail to the tutor at HP and they learn to find resources from the library as well as from the website and finally they have to consolidate into a presentation."

Three students, a teacher, and a mentor from HP were involved in the project. The teacher discussed the project with the students regularly. One of the students collated the ideas and questions generated. The students then e-mailed the ideas and questions to the mentor twice a week. In return, the mentor provided the students with some websites and notes for their research. The teacher acted as the facilitator and looked through the comments and content sent by the mentor. The group did a project on classification of plants that covered many areas such as classification of plants and disposal of seeds. Practical activities such as how many days a particular kind of seed took to grow and which type of seed would grow the fastest were conducted. Information was collected from the experiments, textbooks, and websites.

Digital cameras were used to capture the shapes of the leaves with different types of edges. The findings were presented in *PowerPoint* slides to both the mentor and the classmates at the end of the project.

The teacher commented, during the interview, that the students learned more than content knowledge. Through these activities, the students learned how to analyze, evaluate, and make connections to the information they had gathered. They also learned to synthesize, elaborate, imagine, and design a prototype for the purpose of sharing with their mentor and fellow classmates.

IMPLICATIONS TO ELEMENTARY SCHOOLS

From the findings, there are six interrelated implications of how ICT tools can be used to engage students in higher-order thinking in an elementary school environment:

1. The objective of the lesson plays an important role in shaping the development of the lesson. Students are more likely to engage in higher-order thinking when the objective of the lesson is to do so.
2. Orienting activities that support learner autonomy engage students in higher order thinking.
3. Just-in-time ICT skills training supports students engagement in their learning process with ICT.
4. The different types of ICT tools can often be used to complement one another to achieve the instructional objectives.
5. The classification of a particular type of ICT tool is not based only on its features or characteristics but also on how it is used.
6. Good and effective management of the digital instructional teaching and learning resources that ensure seamless and easy retrieval support the integration of ICT into the curriculum.

Objective of ICT-Based Lesson

Depending on the objective of the lesson, ICT tools are used to engage students in higher-order type of thinking. Teachers have to be clear about the objectives of their ICT-based lessons. The objectives of the lesson determine how an ICT tool is used. In an interview with a teacher after a lesson observation, she explained that the main objective of her lesson was for her

students to learn beyond the basic and content knowledge. Her students were required to gather information from the Internet and later evaluate, organize, and present their findings to the class. The teacher was clear about the higher-order thinking she was trying to engage the students in.

There were also instances where the ICT tools were used to support the teaching and learning of basic content knowledge only. For instance, in one of the Science revision lessons in the classroom, the CD-ROM titled *Tutor-on-Demand* was used to reinforce the topic on simple machines. The video and animation clips found in the software were used to reinforce the content and concepts taught earlier. This facilitated the students' revision of the concepts for the Primary School Leaving Examinations to be held in October 2002. The objective of the lesson was clearly stated by the teacher in the lesson plan.

The previous discussions reveal that the objectives of the lesson are crucial. When the objective of the lesson is to engage students in higher-order thinking, students are more likely to engage in such thinking.

Orienting Activities

Orienting activities that support learner autonomy help students to be more engaged in their learning. Lim, Chai, Teo, and Chye (2002) stressed the importance of orienting activities in ICT-based lessons. These orienting activities include introductory sessions to ICT tools, advance organizers and instructional objectives, activity sheet and checklist, and ICT and non-ICT tools for post instructional reflections. During the ICT-based lessons, many of these activities were observed. As an introductory session, the teachers demonstrated how to log into the network, locate the computer programs, navigate within the software programs, and use certain features of the program. For instance, a Science teacher demonstrated the use of the data loggers and its accompanying software to her students before the hands-on session. The teacher rationalized during the interview that such a demonstration would minimize classroom management problems, and "improve my students' engagement on the learning task."

The use of advance organizers and instructional objectives were especially prominent in one of the Science lessons carried out in the computer laboratory. The teacher first recapitulated the different types of pollution and presented a concept map of the interrelated issues of pollution. Before the students began their Internet search for issues pertaining to pollution, the teacher presented clear and concise instructions on the conduct of the

search. The instructional objectives of the lesson were also clearly communicated to the students in the next two *PowerPoint* slides. A group of students in the focus group interview commented that the Science lesson was organized as "they know what to learn and what to look out for in the web."

Activity sheets and checklists were used in two of the lessons observed—an English composition lesson and a Chinese lesson on proverbs. In the English composition lesson that was conducted in the classroom, activity sheets were given to the students after the teacher-led class discussion on the topic. The activity sheets acted as cues for the students to focus on the different parts of the composition, namely the setting, problem, solution, and closure. The worksheets that were used in the Chinese lesson were more for the reinforcement of the basic content knowledge taught.

In most of the lessons observed, students were assigned post instructional assignments or reflections to help them engage in higher-order thinking. In such instances, both ICT and non-ICT tools were used. The most commonly used ICT tools were *PowerPoint* and *Word* for the purpose of presentation and composition writing, respectively. For instance, students were asked to construct their own *PowerPoint* presentation slides and present to their classmates after they had searched the Internet and the CD-ROM for the necessary information. Students were involved in searching, synthesizing, evaluating, and presenting the data they had retrieved. The *PowerPoint* helped them to present what they had collated.

Non-ICT tools were also used for post instructional assignments or reflections. The students were sometimes asked to hand up their concept maps or draft of their essays using non-ICT tools such as writing pad. Verbal question and answer sessions could also be seen as instructional activities that engage students in higher order thinking. The probing and questioning by the teachers helped the students to be more focused. The orienting activities discussed in this section help students to be more focused and on task, and hence, students are more likely to engage in higher-order thinking.

ou:<Left Sub>Just-In-Time ICT Skills Training

Just-in-time ICT skills training provides the necessary knowledge and skills for students to use the respective ICT tools for the purpose of learning. Very often, students need specific technical skills of using the ICT tools to accomplish the tasks assigned by their teachers. In the case study, ICT skills were taught to the students just-in-time, during and prior to ICT-based lessons. In one of the Science inquiry lessons conducted in the computer laboratory, students were required to collect and analyze information from the Eyewitness Encyclopedia CD-ROM. Just-in-time computer skills were taught. Using the computer and data projector, the teacher first showed the

students how to search for the information, and then went on to demonstrate how to toggle between the *PowerPoint* program and the CD-ROM. This enabled the students to quickly extract the relevant information to be included in their *PowerPoint* presentation. In that lesson, the students were also taught how to use the design template in *PowerPoint.*

In another Science lesson, it was observed that the students were proficient in their Internet search skills. The responses from the students in the class confirmed that they were taught these skills prior to this lesson. Both students and teachers interviewed expressed that ICT skills were best taught as and when required. For example, students who were involved in the school's news team, projects, and competitions were taught the necessary technical skills of using the respective ICT tools as and when the need arose and just-in-time for the event.

Complementing Roles of ICT Tools

The different types of tools are often used to complement one another. In several of the lessons, more than one type of ICT tools was used to engage students in higher-order thinking. In a few instances, the Internet complemented *PowerPoint*. In these lessons, students were instructed to search for relevant information and materials from the Internet and subsequently presented their findings using *PowerPoint*. In the HP Mentoring Project as described by the teacher, both the e-mail and *PowerPoint* related skills were taught just before each phase of the project.

Classification of Different Types of ICT Tools

The classification of a particular type of ICT tool is not based only on its features or characteristics but also on how it is used. From the case study, the same tool was used very differently among and within the lessons. For example, *PowerPoint* was used quite differently in the lessons observed. Most commonly, it was used as a constructive tool for students to construct and present the knowledge they had collected, analyzed, and synthesized. In other lessons, it was used as an information tool by the teachers to present instructions and information to their students. In one of the English composition lessons conducted in the classroom, the teacher used *PowerPoint* to create a simple scenario to stimulate creative thinking among her students. In this instance, this tool could also be seen as a situating tool.

Although the data logger was usually used to facilitate learners' collection and interpretation of the data during their experiments, the teacher who was observed carrying out the experiment using the data logger said that she intended to use the ICT tool to mediate her students' exploration and construction of their own knowledge. The data logger then became a constructive tool instead of a tool just for the collection and interpretation of data.

During the interviews, one teacher stated that the LEGO Mindstorm that was used in the National Junior Robotics Competition was mainly used by the students to practice the creative construction of the robots. During the competition, the students were given scenarios and tasks for the robots to perform in the competition playing field. Hence, this tool could be a constructive tool as well as a situating tool, depending on how it was used.

Effective Management of Digital Instructional Resources

Throughout the period of the case study, it was observed that both the teachers and students used the Virtual Drive Network to retrieve the required computer software programs for the purpose of teaching and learning. All computer software programs and available CD-ROM titles were found in the different academic subjects folders in the Virtual Drive Network. The good and effective management of the digital instructional resources had made the integration of ICT into the curriculum easy and seamless. Teachers and students alike needed no extra effort to use the resources that were housed in the system; all they needed was a computer that was connected to the school computer network. All the teaching and learning resources that were housed in the school's network system could then be seamlessly retrieved anytime and anywhere within the school.

Both the teachers and students were very familiar with using the management system. All the teachers interviewed were aware that "…the kids [students] are comfortable with it." All three teachers interviewed also expressed the usefulness of the Virtual Drive Network and how it had helped them in their teaching. Effective management of digital instructional resources that ensure seamless and easy retrieval supports the integration of ICT into the curriculum.

CONCLUSION AND LIMITATIONS

Limitations

There are four main limitations in this case study. First, the case study provides little basis for generalization. However, the primary intent of this case study was not to understand other cases. The main purpose was to maximize what we could learn from this case study on how ICT tools could be used to engage students in higher-order type of thinking. To this end, the context of the study was elaborated in detail to address this limitation—a rich content was provided.

The second limitation is the different classification of ICT tools by researchers. The different classifications have implications on how the data is being analyzed. For example, Barab, Hay, and Duffy (1998) classified the different types of ICT tools according to their uses. They are (a) information resources, (b) content contextualization, (c) communication tool, (d) construction kit, and (e) visualization/manipulation tool. Although there are differences in this classification as compared to those used in this article, it does not mean that one type of classification is better than another; rather, it shows that there can be more than one way of classifying the different ICT tools.

The third limitation is the lack of evidence on whether higher-order thinking skills are developed. Although the findings highlighted the actions of students that were associated with engagement in higher-order thinking and teachers' reflection of how the activities promoted higher-order thinking, no instrument was used to measure higher order thinking. As the aim and focus of the study was about how ICT tools engaged students in higher-order thinking, it would not be a serious flaw of the study if it failed to show that students' engagement with ICT led to an improvement in higher-order thinking skills. However, such an instrument can be constructed for a follow-up study.

´:The last limitation is the researchers' assumptions and biases. Recognizing that their assumptions and biases could affect the data collection and its outcome, the researchers were open about their assumptions and biases from the very start of the study. To overcome the disadvantage of having no third party in the data collection process, data analysis within each method, between methods, and within the case took place alongside data collection and data processing. Having ongoing analysis had two advantages. First, they helped to undo errors in the field. Lesson field notes and transcriptions of the interviews were completed very promptly. This allowed time for the

researchers to look through the notes and reflect upon how the data collection processes could be fine-tuned along the way. Second, the ongoing analysis provided opportunities to refine the research methods to reflect a better understanding of the context. There were continuous efforts to triangulate the observations and the interviews conducted. However, at times, it was obvious that the interpretation of the researchers and that of the participants mediated the data. To address this, the researchers constantly questioned their own assumptions.

CONCLUSION

From the findings and discussions, it is clear that ICT tools play a neutral role. It can be used to engage students in higher-order thinking or otherwise. How the tools are being used is more important than what types of tools are being used. The lesson objective plays a pivotal function in shaping the flow of the lesson. Orienting activities that promote students' autonomy, just-in-time computer skills, and the good management of digital resources, help in the teaching and learning processes. In addition, the different types of ICT tools can often be used to complement one another to achieve the intended instructional outcomes. Last, the classification of the different types of ICT tools depends not only on its features or characteristics but also how it is used.

The accounts in this article have described what actually took place in the ICT-based learning environment and how the ICT tools were used. Teachers, instructional designers, and other stakeholders of education may then reflect upon these accounts and formulate their own strategies on ICT integration.

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