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TECHNOLOGY-BASED SCIENCE CLASSROOM: WHAT FACTORS FACILITATE LEARNING?

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Abstrak: Mempelajari sains rendah termasuklah memperoleh kemahiran proses sains. Kajian ini meneroka penggunaan bahan pengajaran berasaskan web yang dibangunkan untuk mengajar kemahiran proses sains, khasnya kemahiran mengawal pemboleh ubah. Kajian kes kualitatif ini cuba mencari faktor-faktor yang mempengaruhi pembelajaran dalam persekitaran berasaskan web. Analisis data lisan dan bukan lisan mendedahkan bahawa terdapat beberapa faktor yang mempengaruhi perolehan kemahiran proses sains. Empat faktor timbul daripada kajian ini: (1) bahan pengajaran berasaskan web, (2) susunan fizikal, (3) peranan guru, dan (4) kesediaan pelajar. Artikel ini membincangkan dapatan-dapatan ini dan implikasinya kepada pengajaran dan pembelajaran sains rendah dalam persekitaran pembelajaran berasaskan web.

Abstract: Learning primary science includes the acquisition of science process skills. This study explores the use of specifically designed web-based instructional materials in teaching these science process skills, particularly the skill of controlling variables. This qualitative case study attempts to uncover the factors that influence learning in a web-based learning environment. Analysis of verbal and non-verbal data reveals that there are various factors that influence the acquisition of science process skills. Four factors emerged from this study: (1) the web-based instructional materials, (2) the physical setting, (3) the role of the teacher, and (4) the students readiness. This article discusses these findings and their implications to the teaching and learning of primary science in a web-based learning environment.

INTRODUCTION

Learning primary science goes beyond scientific knowledge acquisition since it includes the acquisition of cognitive skills such as the science process skills. Gagne (1963) views science process skills as the foundation for scientific inquiry, and knowledge is developed inductively from sensory experience. These skills consist of basic and integrated science process skills. The Malaysian Primary

Science Syllabus has given due emphasis to the acquisition of both basic and integrated science process skills. There are 12 skills outlined in the syllabus. The skills of observation, classification, measurement and using numbers, time and spatial relationships, making inference, prediction and communication are categorized as the basic science process skills. While the skills of controlling variables, interpreting data, defining operationally, formulating hypotheses and experimentation are categorized as the integrated science process skills.

Learning integrated science process skills at the primary level requires students to be at the formal operation stage according to Piaget's stages of cognitive development (Inhelder & Piaget, 1958; Brotherton & Preece, 1995). However, majority of the primary school students are operating at the concrete operational stage (Shayer, Kuchermann, & Wylam, 1976; Palanisamy, 1986). Many research studies (e.g., Allen, 1973; Klahr, Chen, & Toth, 1999) have shown that teaching primary school students on integrated science process skills require some form of specific training. Klahr (1998) used direct instruction in teaching Grade Five students to control variables while Quinn and George (1975) used film loops in teaching Grade Six students to formulate hypotheses. This study adopted the use of technology, specifically the web-based instruction in teaching the skill of controlling variables. In this article, the term *web-based instruction* and *web-based learning* is used interchangeably.

Web-based instruction offers several advantages and one of them is that it supports hypermedia environment. Tulhurst (1995) defines hypermedia as a computer-based system that allows interactive linking of multiple format information, and this supports a non-linear way of instruction. This non-linear approach enables users to make decisions on which path or section to explore and increases students' control over their learning. Besides supporting the non-linear pathways, hypermedia environment also supports various combination of media format such as text, image, graphics, sounds and animation. This multiple media format motivates students (Tulhurst, 1995) and extends their attention span (Kumar, 1995). The animation in simulation enables students to visualize better particularly, in acquiring the science process skills. These animations, which are dynamic and interactive, may activate the students' imaginal codes. This activation facilitates encoding and memory storage of information (Driscoll, 2000). These are among the design features that were adopted in the web-based instruction of this study.

Technology-Based Instruction and Science Teaching

The terms web-based instruction (WBI), web-based learning (WBL) and web-based learning environment (WBLEn) surfaced and they are used in accordance to the learning context. In this study, WBI and WBLEn is used interchangeably to refer either to the programme or the learning environment. Most research on WBI looked into the products of learning. The effects were either on achievement, attitude or acquisition of skills. The most common research done on WBI is to investigate the effect of WBI on students' achievement.

Sarapuu and Adojaan (1999) investigated the use of readily available web-based materials to develop higher order thinking skills such as making analysis, synthesizing and evaluating, among primary and secondary school students. They found that the secondary students performed better than the primary students in the ability to analyze and synthesize. However, the overall performance in these skills was not significant. They also found that the web-based materials managed to motivate students to become more interested in the subject matter, which is on environmental and natural sciences, specifically in the Estonian vertebrates and plants. Based on the findings, they concluded that the development of higher thinking skills did not significantly depend on the web materials, but on the nature of the problem solving tasks provided during the training phase.

Daniel and Rohaida (2001) used a specially designed WBI Module, *Elements of Life* (ELF), for students to learn about carbon, hydrogen and oxygen as the three basic elements of life. Sulphur was later introduced as a cognitive conflict. Many resources on these four basic elements were linked to this module. Pre and post quizzes were administered to the 13 Form Four students who participated in the study. They were also interviewed at the end of the study. The students indicated that they now had a better understanding of the basic elements of life found in living tissue. The result of the quizzes showed that the students were now able to visualize science as a whole entity rather than as separate disciplines of biology, chemistry and physics.

One of the features of WBL is communication, which can be in the form of synchronous or asynchronous. Jarvis, Hargreaves, and Comber (1997) studied the impact of communication via e-mail in enhancing the acquisition of science process skills among primary rural students. The electronic communication provided a means for students who had limited access to peers of similar age, particularly for students in isolated rural schools to communicate. Findings from in-depth structured observations and interviews revealed that students acquired a variety of science process skills, particularly observation and recording data. The use of e-mails had also indirectly enhanced the students' information technology (IT) skills. Furthermore, the teachers felt that the use of e-mails had enhanced cluster cohesion and communication among staff and students in these rural schools.

Several factors have been identified in studies related to computer-based technologies and science teaching (Tebbutt, 2000; Ng & Gunstone, 2003).

Among the factors that influence the use of technology in science teaching are: (1) the difficulty in getting access to computers, (2) associated equipment or hardware, (3) time, (4) teachers' lack of skills and knowledge in information technology and communication (ICT), and (5) lack of financial support. All these factors were found to have hindered teachers from teaching using computer-based technologies.

Factors Influencing the Acquisition of Science Process Skills

Literature suggests that there are various factors that influence the acquisition of cognitive skills such as science process skills. The teacher plays an important role in learning, including the acquisition of science process skills. Marzano, Pickering and Pollock (2001) assert that although schools make little difference, that is only approximately 10% in students' achievement, the most important factor affecting students' learning is the teacher. According to them, teachers can have a profound influence on students' learning even in schools that are relatively ineffective.

Harlen (2000) identifies three main aspects of the teacher's role: (1) setting up the learning environment, (2) organizing classroom activities, and (3) interacting with students. Among these three aspects, the most important aspect is teachers' interaction with students during their teaching. A teacher has to help students in engaging them to think while performing the tasks given. Johnson (1997) also found that the teacher's role during his study on a technology-based learning environment was crucial. According to him, the teacher should ask the right questions in order to engage students' thinking, facilitate them by asking how they would test their ideas, encourage them to further explore and serve as expert when they needed one.

Apart from the teacher's role, readiness is another factor that influences the acquisition of science process skills. Students' readiness is perceived as learner's developmental level of cognitive functioning (Driscoll, 2000). It is the cognitive maturity that is assumed to determine the extent to which learners are capable of learning. Therefore, students' cognitive level should be taken under consideration in teaching students. Based on Shayer and Adey's (1981) taxonomy, students being at the concrete level of Piagetian Cognitive Development will not be able to handle multiple variables. They will be able to vary more than one variable only when they are at late concrete and formal level. This is due to the fact that concrete thinkers are not cognitively 'ready' to handle multiple variables.

Another factor that affects learning is students' readiness. Ausubel, Novak, and Hanesian (1978) sees readiness as a function of previously acquired knowledge. They emphasized that what students already know influences their learning.

Readiness in this sense depends on the learner's cognitive structure. What they already know facilitates subsequent learning. Taking this point into consideration, it is important for teachers to know their students' prior knowledge before proceeding on to other lessons.

METHODS

This qualitative case study is part of a study aimed at uncovering the learning process primary school students undergo in a WBLEn (Rohaida, 2003). The study explored the use of a specifically designed WBI material in teaching science process skills, particularly the skill of controlling variables. For the purpose of this article, the focus is on factors that influence students' learning in science. Specifically, this article attempts to discuss the factors that influence the acquisition of integrated science process skills among Grade Five students in a WBLEn.

The participants comprised of 19 fifth grade students: 11 girls and 8 boys of middle class socioeconomic background. They were chosen based on purposive or purposeful sampling, as Merriam (1998) argues that the sample should be comprised from whom the most can be learned. The main criterion for choosing these students is their ability to talk and express themselves freely while being audio and videotaped.

The study was conducted in the school's computer laboratory. The students were divided into groups of two's and three's. There were a total of seven groups. Three of these groups had a computer each, while the other four groups had to share computers. Audio recorders were placed at each of the groups' computer terminals to capture the groups' conversation as well as conversations between the teacher and the students.

Verbal data is the main data source that allowed the researcher to look into the students' thoughts while interacting with the WBI materials. Besides verbal data, the students were videotaped to capture the non-verbal behavior. The students were also required to write their reflection in their diaries. The diaries were collected at the end of every lesson. The study was carried out for a period of five weeks, including a week for the students to familiarize with the research tools as well as the 'new' learning environment. Although audio and video recordings were made, data collected during the familiarization were not considered.

The study utilized a specially designed WBI material, Science Process Skills in Scientific Exploration (SPicE), a prototype version and focused only on the skill of controlling variables (http://inquiry.sirim.my/~spice/ index.html). SPicE was developed in-line with the Malaysian Primary Science Syllabus and presented in the national language. An account of the development of SPicE is provided in Rohaida and Kamariah (2000), and Rohaida (2001).

A printed guide that outlined the learning objectives and the learning tasks was given to each student. Students were required to complete the targeted task that was based on SpicE. After they had completed the given task, students could explore any other sections of SPicE.

During the first week, students were familiarized with the research tools as well as the 'new' learning environment. In the second week, students performed a hands-on pendulum experiment. They investigated the effects of various types and different lengths of strings on the number of oscillations. All experimental procedures were available on SPicE and they had to complete an electronic worksheet that was sent to SPicE database. Feedback was given to the students in class. In addition to the hands-on activities, students were also encouraged to participate in an electronic forum, another feature of SPicE. The teacher posted two questions to initiate discussion since the electronic forum was new to the students.

The students explored the simulated activities provided by SPicE in the following week. There were three simulated activities and each activity had three to five different tasks of various difficulty levels. During the fourth week, the students explored other websites. SPicE provided six links and the links include both local and foreign primary science-related materials. However, only one link is primarily related to science process skills, while the other sites are science content-oriented. In the final week of the fieldwork, the students tried the Quiz in SPicE. Ten multiple-choice questions with asynchronous feedback were provided in this quiz. The quiz served as a form of self-assessment.

ANALYSIS OF DATA

The constant comparative method of analysis (Merriam, 1998) was used in the data analysis. All audiotapes were transcribed verbatim. The videotapes were also transcribed in the form of descriptions of students' behaviors. Forum entries were downloaded from SPicE database and analyzed based on the questions posted as well as responses to these questions. The diaries were reviewed and only relevant entries were extracted.

All these data were first reviewed. Recurring words and phrases were then coded. Only data reflecting the phenomena that influenced the students' learning were analysed. These codes were further analyzed by creating category and subcategories to develop several main categories (Strauss & Corbin, 1990).

The initial categories that emerged were *role of the teacher* and *point of saturation.* These factors were based on the events or episodes from the data. For example, non-verbal behaviors such as students exploring SPicE without any show of enthusiasm and instances where students were yawning were categorized under point of saturation. Episodes showing the teacher assisting the students in conducting the experiment and exploring SPicE were considered as role of the teacher. These factors were then refined and point of saturation was renamed *students' readiness,* to better reflect the phenomenon.

FINDINGS

The analyses revealed four factors influencing students' acquisition of science process skills. The four factors identified have facilitated as well as inhibited the students' acquisition of the science process skills. The factors are: (1) design features of the WBI, (2) physical setting of the computer laboratory, (3) role of the teacher, and (4) students' readiness.

Facilitating Factors

Design Features of the Instructional Material

The design features such as interactivity, asynchronous and synchronous feedback, learner-controlled, and simulations seemed to have supported and facilitated learning. For example, interactivity had allowed for social interaction in the form of participation in the Forum. From the Forum database, it was found that all the students participated although participation was not compulsory. Students found this section helpful as written in one of the diaries, "The Forum made me understand science better and we were able to exchange ideas". The students also indicated that the Forum gave them opportunities to ask and post questions to either their teacher or friends and also to respond to their friends' questions. Such interaction might have generated collaborative discourse that could enhanced their acquisition of the skills, as illustrated in the following audio transcript:

> Teacher: How did SPicE help Ally in learning science?
>
> Ally: We could answer questions posted by the teacher, or we could post questions, or we could answer our friends' questions.

Teacher: How is that … when did you answer your friends' questions?

Ally: As in the Forum, whenever I do not understand something … I'll post the question. As for my friends (questions), I'll try to answer them.

The Forum provided asynchronous feedback. Synchronous feedback was also imbedded in the Quiz. This form of feedback could have motivated the students as they were seen to keep on trying to do more questions:

Zack: *Eh!* Try again … that's incorrect!

Syamsul: How did you know?

Zack: 'Try again' … can you see? (pointing at the screen, referring to the feedback)

Syamsul: Bring it here! Try again! Try! Try! … and the one that is from low to high! Ha!

Another feature that could have facilitated students' acquisition of science process skills is the simulations. Simulation helped them to visualize since they were able to observe the immediate effect of the manipulation of variables, "It (the program) has diagrams … for example *tanjakan* [one of the simulated activity]… you could observe (the effect) immediately. If it's like this [referring to a diagram in a book], you can't really imagine". In another instance, a student, Ally explained that SPicE assisted him in learning the skill of controlling variables as he could manipulate the variables and observe its effect immediately and directly:

Teacher: Yes … now you have learnt about variables. How did SPicE teach you about variables?

Ally: Because it (variable) changes when being changed!

Teacher: Yeah?

Ally: If we want to change … ha … change … like the Fish Activity … its temperature (referring to the link, Fossweb, under the activity Aquarium) ha … something like that …

Teacher: So, when you change (something), you can see the effect immediately?

Ally: Yes, I can see (the effect) immediately!

SPicE also provided computer-generated graphs based on the results obtained from the simulated activities. Students found data presented in graphical form to be more meaningful as it was easier to compare the results and make predictions.

Physical Setting of the Computer Laboratory

Although the computer laboratory had 20 computers connected to the Internet, only 15 computers were functioning. Since there were 19 students, only three groups had a computer each while the others had to share. The students appeared to work well in groups particularly in performing the hands-on activities provided by the computer program. Groups that shared computers were observed to interact more compared to their peers who had a computer each. Groups that shared computers were seen to discuss and articulated their ideas before solving the problems. Working in groups enhanced cooperative and collaborative learning, and good collaborative discourse transpired from their discussion. For example, in one of the group's discussion, students construct meaning by articulating their ideas and explaining the phenomenon that they had just observed in the simulated activity:

Illana: That's wrong! (Referring to the result of the task).
Eh … please think! How could a heavier ball travel further?

Halimah: *Eh* … the heavier ball would travel further because it's big!

Illana: *Eh* … the smaller ball would travel further because it's lighter! It is … lighter … the smaller ball is lighter!

Halmah: *Eh* … listen here … if you measure its circumference, the bigger ball has a bigger circumference. This means it can travel further … well … it's up to you … if you want to listen to me or not, OK!

Thus, it can be inferred that the physical setting of the laboratory had facilitated collaborative discourse and this indirectly could have enhanced the acquisition of scientific knowledge and science process skills.

Role of the Teacher

The teacher's role in this WBLEn was not only as the disseminator of knowledge, but includes facilitator, moderator, technical and content specialist as well as translator to the students. The teacher facilitated in various ways: familiarizing students with the SPicE programme, including creating their own user names and passwords; registering for some of the links; and registering for free e-mail services. She assisted them in troubleshooting computer problems as well as guiding them in their learning tasks.

During the hands-on activities, the teacher facilitated and assisted almost all of the groups in assembling the apparatus. The students were asked to demonstrate the techniques of taking measurements of the different lengths of the string, timing and counting the oscillations. The teacher then corrected and guided them the correct technique in performing the task:

Teacher: Yes… so…how did you measure? Ha…take the (ruler) … I would like to see … (the student demonstrated). Hmmm …this has to be corrected!

Zack: Where about?

Teacher: You have to adjust. Alin …help them. Not help, but do it together. Don't hold it like that, Zack! Let go! What's the length? Until which point? Twenty …

Zack: … five!

Teacher: Zack! Read the readings carefully … OK? Don't turn it! It's not tied up yet! Try tying it up! That's the reason…you have to read the instructions… Ha… look carefully ….again….measure it! Can you do it?

This was done to ascertain that they used the correct technique in performing the Pendulum experiment. Correct and proper technique would ensure valid experimental results or data. In another situation, the teacher assisted Group F in producing computer-generated graph in one of the simulated activities:

Syamsul: How do we get computer-generated graph?

Teacher: Just press (the icon)…

Syamsul: OK.

Teacher: If you want to move the screen …it's like this, OK? Look here…now it displays the graph for you!

Syamsul: Oo...ha…ah…

The assistance provided was necessary because SPicE was new to them and they had not experienced such features before. Another aspect that needed facilitation was posting and responding to messages in the Forum. Initially, they were not able to send messages and seek the teacher's help:

Alin: What is the question?

Zack: How do you …ah…send (the message)?

Teacher: What is it? Hmmm…

Zack: Send message?

Teacher: What do you want to do? Post message … if you want to send a new message … (demonstrated the feature) … meanwhile, read the teacher's comments first!

Students looked up to the teacher as an expert in the subject area. In this learning environment, they tended to refer to the teacher's comment or response in the Forum just to make sure that they were on the right track:

Illana: What is the meaning of *tanjakan* (ramp) and why do we need to collect information, such as variables, hypotheses in an experiment? (reading the posted question)

Halimah: What is it, …huh? *tanjakan* cannot …

Illana: I don't know!

Halimah: If *tanjakan*, just ask the teacher!

Illana: Try…try…try looking at the teacher's response… (Read the teacher's response)

Halimah: Yes…yes! …I know this…I know this!

Illana: I still want to have a look at the teacher's response!

The examples presented indicated that the teacher played the roles of a facilitator, moderator as well as an expert. These roles could have facilitated learning.

Inhibiting Factors

Instructional Materials

Besides facilitating student learning, poor design could slow down the downloading of the instructional material and this could hinder learning. Although various aspects were taken into consideration during the development of the WBI material for efficient downloading, the students felt that the program was slow. For instance, a video recording revealed that one of the student, Atiqah was staring blankly at her monitor screen while waiting for the section *Cabaran SPicE* or the Quiz s to download. She then straightened her headscarf and later pressed both her hands against her cheeks while looking straight at the monitor. On the other hand, another student expressed her frustration while waiting for the section to download by *talking to her computer*, "Hurry-up … if you'd reach till here (referring to the full display of the section), I'd give you (the computer) 10 cents!" These verbal and non-verbal gestures indicated that frustrations might have set in among the students.

Apart from the slow downloading, students were also frustrated when their work was found missing. SPicE did not have a feature where users could save their work before submitting them to the database. On one occasion, members of Group C had to re-enter their work since there was some error in the earlier submission to SPicE's database. The work could not be found and there was no feature to trace the missing work. The students were frustrated:

Halimah: Oh! No! We have to key in again?

Illana: *Ala*…I hate this!

Hashim and Ally reinforced the feelings of frustration in their diary, "When we were completing the 'hands-on' activities, we accidentally exit this section. And when we reopened the section, all our answers that we've keyed in previously were gone. So, I had to key in the answers again."

Distraction was another factor that could impede the students' acquisition of the skills. The Forum used in SPicE was a free service and it came with lots of advertisements from sponsors. The advertisements distracted the students from their own task as they were busy trying to link to the advertisement.

The medium of instruction in Malaysian schools is the national language, Bahasa Malaysia. English is taught as a second language and the students in this study had a poor command of the language. Hence, they tended to avoid exploring the links provided in SpicE as exemplified by Said's diary entry, "I have problem exploring the links which were in English."

Students' Readiness

In the context of this study, student's readiness refers to two aspects: the state of the students' attentiveness and their cognitive preparedness. Attentiveness refers to the attention span. Students were found to be less attentive after a period of time. This was particularly evident when the student had to wait for the web-based program to download.

The aspect of preparedness was prevalent when the students were unable to solve problems related to the manipulation of multiple variables that were integrated in the web-based program. Instead they solved the problem by manipulating one variable at a time. This suggested that students are not cognitively ready to meet the demands of the instructional material.

Physical Setting

The computer laboratory was arranged in an almost semi-circular row, with students facing the front of the laboratory as well as the computers (Figure 1). The teacher found it quite difficult to ascertain if the students were following the instructions and explanations given. This was because the teacher could not see what the students were doing at their computers. The teacher tried moving from one group to another but it was quite difficult with such a setting.

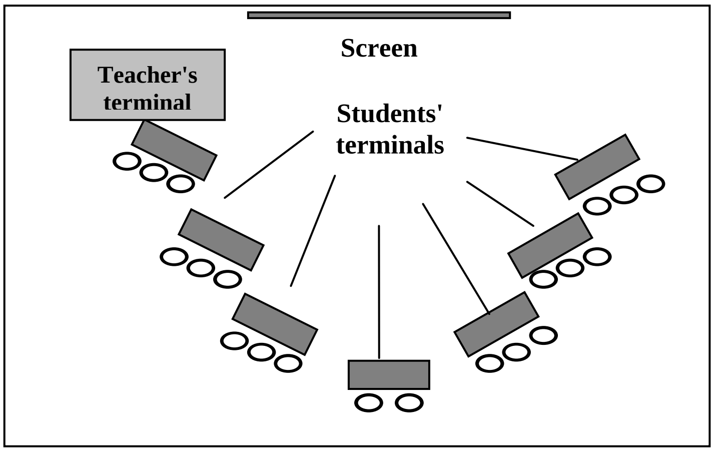

Figure 1. Layout of the laboratory

DISCUSSION AND CONCLUSIONS

The findings showed that learning science in a WBLEn was influenced by four factors: (1) WBI materials, (2) physical setting, (3) role of the teacher, and (4) students' readiness.

The present learning environment utilized SPicE as the instructional materials. It had features such as interactivity, asynchronous and synchronous feedback, learner controlled, and simulations that were known to support and facilitate learning. The electronic worksheet could have also enhanced learning, as the results of this study revealed that students would reflect on the tasks that they had performed only when prompted by the electronic worksheet. Furthermore, the high rate of participation in the forum or electronic discussion could imply that the WBI complement the existing practise of face-to-face instruction. Thus, WBI should be seen to augment rather than to replace face-to-face delivery and interaction.

Besides the design features, SPicE could be a better instructional material if the programme could execute instantaneously. Expressions of annoyance reflecting their frustrations, particularly while exploring the Quiz and some of the links were frequently heard or noted. During the development of SPicE, a lot of attention was given to account for efficient downloading. SPicE was kept under 20 K for the first level of the web page. Graphics was kept to a minimum and sound was not incorporated. However, the presence of worms (*Sircam* and *Red Worm*) could be the reason for the slow-downloading and slow response rates. During this period, the students were exploring the Quiz and related links.

Another factor that influences the acquisition of the science process skills is the language used in the computer programme. SPicE was developed to suit the current Primary School Science Syllabus and presented in Bahasa Malaysia. Having SPicE in the mother tongue language is an advantage to the students since they could comprehend SPicE better. Moreover, the scientific terminologies used in SPicE were congruent with the terms used in class. This could have facilitated them in acquiring the intended skills. Some of the links made available in SpicE, however, they were in English and students felt uncomfortable exploring these sites.

The physical setting or environment also played an important role in the present learning environment. Johnson (1997) regarded an ideal environment as a significant factor in promoting learning. This environment includes the physical setting of the classroom. Based on observations, the physical setting of this study could have hindered direct interaction between students and teacher, especially during the latter's explanations on various concepts or issues. Students were observed to be busy exploring and manipulating SPicE, while seemingly paying attention to the teacher. The situation could probably be improved with the rearrangement of the physical setting. Computer stations could be arranged facing the wall, leaving empty spaces in the middle. Chairs could be brought to the middle and students could sit in this empty space while listening to the teacher. The students could only go back to the computer station once they were ready to work with the computer.

The findings of this study also revealed that students who shared computers interacted more with their peers as compared to their counterparts who were not sharing. Social interaction mediates learning. According to the Vygotskian perspective, learning is a social construction of knowledge. Knowledge is constructed through engaging socially with the teacher and peers, through conversation and activities of common concern. It is therefore suggested that the physical setting of the WBL should be arranged to allow for more interaction among students.

Another factor that seemed to influence learning is the teacher. Johnson (1997) pointed out that the role of the teacher is important in facilitating learning by asking questions, giving directions, suggest strategies and guiding students. These were exhibited in the present study where the teacher had to guide, especially at the beginning of the study. She posed questions for the students to reflect. She suggested strategies that can be employed in solving some of the problems. Besides facilitating, the teacher was also the expert. Whenever the students were facing with problems, they would always refer to their teacher.

Besides being a content expert, the teacher was also the technology expert. She helped the students with the technical aspects such as ways to access the programme, navigating through the different sections and keying in inputs into the electronic worksheet. Nevertheless, the teacher's role as the technology expert gradually declined as the students became more familiar with the environment. The teacher also acted as a translator. Since the students were not fluent in English, the teacher translated some of the English scientific terminologies. The role played by the teacher in this current learning environment had changed from a mere knowledge provider to a more complex role. This transformation in the teacher's role could have facilitated the students' learning. This finding is similar to Abtar Kaur's study (2001) who found that the teacher played six different roles in the WBLEn: technology expert, content expert, motivator, promoter of cooperative learning, bilingual expert, and monitor of student's progress. She asserted that these roles seemed to enhance students' higher thinking skills, content skills and information skills.

The findings of this study illustrated that students' readiness seemed to be another factor affecting students' acquisition skills. Generally, this learning readiness is perceived as a learner's developmental level of cognitive functioning (Driscoll, 2000). The cognitive maturity of learners determines the extent to which the learners are capable of learning. This is one form of readiness that was observed in the study. The students had difficulties in handling the final level of all the three simulated activities. All these activities involved manipulation of multiple variables. This finding indicated that the students, being at the concrete level of the Piagetian cognitive development, were unable and not cognitively 'matured' to handle multiple variables. This is consistent with the schemas or taxonomy postulated by Shayer and Adey (1981), also based on Piagetian perspective. According to this taxonomy, only children at late concrete and formal level are able to vary more than one variable.

In summary, this study offers some important insights into factors that could influence learning in a WBLEn. These findings could provide some guidance to science educators who may embark on using technology-based instruction, particularly in designing the instructional material, planning the learning environment and enhancing teacher's competencies in such learning environment. Further studies are needed to investigate whether the factors uncovered in this study influence other technology-based learning environments and which of these factors influence science learning the most.

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