**REVIEW ARTICLE**

# Interaction of student's academic background and support levels in a resource-based learning environment on Earth's movement

Wing Mui Winnie So[a] * and Siu Cheung Kong[b]

[a]*Department of Mathematics, Science, Social Sciences and Technology, The Hong Kong Institute of Education, PRC;*

[b]*Department of Mathematics, Science, Social Sciences and Technology, The Hong Kong Institute of Education, PRC*

This research aims to study how a resource-based learning environment (RBLE) helps primary students develop better understanding of the Earth's movement. One objective of the study is to establish a RBLE by creating authentic contexts, selecting appropriate resources, designing relevant tools, and adopting necessary scaffolds. The other objective is to examine the effects of the RBLE on primary students' understanding of the Earth's movement in different classroom settings with varied teaching support levels. Research methodology includes pre-lesson and post-lesson tests to study students' understanding, observation and analysis of lessons to examine the teaching scaffolding employed, interviews and teacher's written reflection after all the lessons to investigate their views of the use of RBLE. The findings indicated that there is an interaction effect between students' academic background and settings of learning, and that the RBLE provides little support to students of low academic background, but is very effective to students of higher academic background helping them to construct an improved understanding of the Earth's movement. The paper suggested an integrated use of teacher-regulated inquiry approach and interactive inquiry approach for the better use of the RBLE.

**Keywords*:*** Earth's movement; inquiry learning; resource-based learning environment; scaffolding

* Corresponding author. Email: wiso@ied.edu.hk

## Introduction

There is an emerging body of research on students' understanding of natural phenomena, including that of astronomy (Vosniadou, 1991), the planets (Bakas & Mikropoulos, 2003; Jones & Lynch, 1987), the day and night cycle (Brewer & Vosniadou, 1994), and the seasons (Brewer & Vosniadou, 1990; Sneider & Pulos, 1983; Trumper, 2001). This body of research is grounded in studies that have been conducted on children's misconceptions and varied understanding of these phenomena. It has aroused the concerns of educators and teachers about children's difficulty in developing an understanding of natural phenomenon with the limited teaching aids. In view of this, there are suggestions of different strategies (Vosniadou, Skopeliti, & Ikospentaki, 2004) to enhance students' understanding, which include the design of virtual environments on the Internet (Bakas & Mikropoulos, 2003) to enhance students' comprehension of planetary phenomena.

This study aims to look into the issue by first considering the different common teaching approaches that have been used in primary classrooms. This is followed by a review of the use of the Internet as a resource-based environment in the learning and teaching of science. The interest is proclaimed by Gilbert (2000) as "surely a theme of great importance for the immediate future of science education". This is followed by the design and development of a resource-based learning environment for primary students to inquire into the topic of the Earth's movement. Learning outcomes and views from students and teachers were studied to capture how a resource-based learning environment helps primary students improve their understanding of the Earth's movement.

## Common practices in primary classrooms

How does a teacher usually teach the topic of the Earth's movements? What teaching strategies are employed? What teaching aids and resources are commonly used in primary classroom teaching?

From the literature, the following vignettes are generally found in primary classrooms: A textbook-based lesson; a mechanical model of the Sun, Earth, and Moon system used as a teaching aid; different objects (such as oranges, grapes, and baseballs) used to illustrate the movement of planetary bodies in a simulation of the planetary movements.

In a textbook-based lesson, the teaching aids are the textbook, photos, and the exercises in the textbook (Glynn, Yeany, & Britton, 1991; Morris, 1995; So, 2002). Generally, the teacher would hold the textbook that contains some photos and lecture to the class. The class of primary students sit in rows of desks, follow the teacher's instruction to read out questions about photos and materials in the textbook, listen to the teacher's explanations, and occasionally respond to questions that are asked.

The use of a mechanical model of the Sun, Earth and Moon system[1] as a teaching aid seems to be a step forward when compared to the previous vignettes. The old and bulky mechanical model of the Sun, Earth and Moon system is usually put on the teacher's desk. The teacher mostly controls the movement of the model manually, and tries to demonstrate to the students how the Earth rotates around the Sun. Some teachers may attempt to involve students by asking them to control the movement of the model.

Websites that claim to have innovative teaching strategies generally use the same aids but with animations and pictures to illustrate the movement of planetary bodies by using different objects (oranges, grapes[2], and baseballs) to symbolize the planetary bodies and to arouse student interest.

Mimicking is said to be an effective way of getting students involved in the learning process[3]. For example, in a school environment a class goes out to the playground to mimic the movements of the Sun, the Earth and the Moon. First, the students need to determine which roles will be mimicked by whom, the teacher demonstrates that the Sun is at the centre of the Solar System, and the Earth orbits around the Sun by asking the designated 'Earth' student to spin while they orbit the designated 'Sun' student. The students usually burst into laughter while they watch their classmates spin as the Earth (So & Kwong, 2003).

These methods of instructions focus on well-organized resources and supervised learning activities from textbooks with learners looking to the teacher for instruction. Teachers and students do not have to actively seek out and search for additional resources or to evaluate whether the resources are relevant and sufficient for learning to occur (MacGregor & Lou, 2004). Hence, the above practices do not seem to optimize available resources to prepare students to learn in the resource-rich environments that are popular.

**Internet-based learning environment**

Ferdig, Mishra and Zhao (2004) suggested that the Web, as an information resource or "global library", is the most promising medium for deploying educational content. The exposure to current and authentic but sometimes inaccurate information available from the World Wide Web can provide students with the environments that support inquiry-based and constructivist learning (Oliver & Hannafin, 2001). Regarding Internet-based learning in primary science, Mistler-Jackson and Songer (1999) have developed the Kids as Global Scientists (KGS) project which engage sixth-grade students in the study of atmospheric science through the use of current imagery and on-line communication in a inquiry-based curricular program. Wallace, Kupperman, Krajcik and Soloway (2000) have developed a Digital Library for Primary 6 grade students' inquiry in science, using it as an information resource that creates the possibility for students to pursue questions of personal interest. Similarly, Kitazawa, Nagal, Kato and Akahori (2005) have developed an e-learning system "Science Net" for science education in the primary school. The system contains schedules of lesson, lesson contents, a bulletin board system (BBS) and reference site. Moreover, Bakas and Mikropoulos (2003) studied the design of virtual environments for the comprehension of planetary phenomena based on primary students' ideas.

There is a lot of recent research supporting science learning in similar environments—teacher, computer, peer, such as the Knowledge Integration Environment (KIE) (Linn, 2000). It takes advantage of internet materials to engage students in four main themes: making science accessible for all students; making thinking visible so students understand the process of knowledge integration helping students to listen from each other; and promoting lifelong science learning. Linn, Clark and Slotta (2003), as well as Linn, Davis and Bell (2004) have further elaborated that the Web-based Science Enquiry Environment (WISE) leverage the commitments and talents of teachers, and the constraints and opportunities of their classroom contexts. Besides, Wang and Reeves (2006) have worked on the Web-based Learning Environment (Web-LE) to improve student motivation to learn science. Furthermore, Blumenfeld, Fishman, Krajcik, Marx, and Soloway (2000) brought a middle-school inquiry and technological science innovation to scale up technological-embedded project-based science. While Barab, Hay, Barnett, and Keating (2000) conducted a virtual solar system project for building undergraduate students' understanding through scientific inquiry using 3-D model they developed.

The above work on learning environments converges on the ideas that a student's understanding evolves through exploration and inquiry in a resource-based learning environment by means of active exploration with rich resources, in addition to, print-based resources. However, the design of the above-mentioned research and projects mainly rested on work with students at secondary levels or above, which may not be directly applicable to primary students. Hence, this study attempts to focus on the creation of a resource-based learning environment for primary students and to examine its effect on students' understanding of natural phenomenon.

**Resource-based learning environment**

There were observations from Hill and Hannafin (2001) that current practices and uses of the Internet are insufficient for optimizing available resources and preparing individuals to learn in resource-rich environments. They commented that tools and search engines are systems on the Web that help to locate potential resources but do not help individuals to determine their meaning or relevance. They also offered the criticism that increased resource availability and access are necessary but insufficient for promoting effective teaching and learning. Hence, they suggested that the potential of integrating multiple resources into a coherent learning environment – a resource-based learning environment (RBLE) – for instruction and learning is considerable. This would enable teachers and learners to work on tasks with support mechanisms that help them locate, analyze, interpret, and adapt information from expanded resources.

RBLEs comprise four components (Hill & Hannafin, 2001). The first component is resources, either static or dynamic, which have a format that ranges from electronic to print and non-print to human. Resources provide complex information which may not be well organized and designed for assigned tasks, forcing learners to interpret and synthesize, and use cognitive skills that are not yet developed to process and manage the resources. The second component is contexts or settings, either real or virtual, that can be externally directed, learner generated, or negotiated, in which learners develop new understanding. The third component is tools (for locating, accessing, manipulating, and communicating resources) that help learners to determine the meaning and relevance of resources. The fourth component is scaffolds, which can be conceptual, meta-cognitive, or procedural and strategic, which are needed to improve a learner’s development of high-order cognitive skills.

Though RBLEs provide a foundation for design practices by aligning activities with the associated tenets and assumptions of the epistemological orientation they support (Land & Hannafin, 2000), RBLEs are pedagogically neutral, and so they can be implemented anywhere along a teaching-learning continuum that ranges from teacher-directed to learner-oriented, or from a highly regulated environment to an open-ended constructivist environment. Case (2003) found that teachers often feel insecure and uncomfortable and are unable to learn effectively in such resource-based learning environments. It is because most of our current students are accustomed to didactic instruction and directed learning. Though directed approaches tend to work better when meeting prescribed goals, they are less effective when critical thinking, problem-solving, and self-regulation skills that are needed by the 21st century are required. Hill and Hannafin (2001) also expressed concern that the appropriate and sufficient conditions for effective teaching and learning within an RBLE are not yet understood.

## Role of scaffolding in inquiry learning

The pedagogical design of multimedia materials and the ways of implementing them in instruction and in classrooms are the most important factors. Research on technology-enhanced inquiry environments suggests that although computer-based tools offer considerable potential, technology per se is unlikely to support students’ inquiry processes (Kim, Hannafin & Bryan, 2007).

Inquiry is understood as engaging learners in identifying problems, collecting information and solving the problem that they have encountered (Curriculum Development Council, 2002; Hover & Horne, 2005). This may be the optimal perspective to take for resource-based teaching and learning. However, inquiry learning can be interpreted as different things by different people (Alvarado & Herr, 2003). Martin-Hansen (2002) proposed three types of inquiry: open, guided, and coupled. Open-inquiry requires learners to take the initiative to pose questions, conduct investigations, and communicate the results, but it seems too demanding for young learners. In a guided-inquiry, assistance is provided to learners by teachers to develop their investigations. Coupled-inquiry combines a guided-inquiry investigation and an open-inquiry investigation, which starts with a teacher-initiated guided-inquiry task as a kind of scaffolding that allows learners to conclude with a more self-initiated open-inquiry task.

In discussing the development of competence in an area of inquiry, Donovan and Bransford (2005) suggested that learners must have a deep foundation of factual knowledge. Learners should also understand facts and ideas in the context of a conceptual framework, and organize knowledge in ways that facilitate retrieval and application. Edelson, Gordin and Pea (1999) realized the implementation of inquiry learning in classrooms presents a number of significant challenges. Hence, Edelson (2001) explored technology-supported inquiry learning as an opportunity for integrating content and process learning using a design framework called the Learning-for-Use (LfU) model. It is a learning process that can be used to support the design of content-intensive, inquiry-based science learning activities. All those integrating content and process together with the design of learning activities offers the opportunity to increase students' experience with authentic activities while achieving deeper content understanding.

Coleman (1998) evaluated the effects of a scaffold explanation-based approach of collaborative discussion on students' understanding on photosynthesis. The findings support the importance of the nature of students' discussion (i.e. explanation) to advance their beliefs about scientific phenomena, and emphasizes the usefulness of explanation and concept-mapping techniques as evaluative measures of student knowledge during collaborative problem solving. Crawford (2000) in his study of a single high school teacher provided a detailed view of the day-to-day processes involved in creating and sustaining a model of collaborative inquiry that require the teacher to take more active and demanding roles than traditionally depicted.

Davis and Linn (2000) in their study using Knowledge Integration Environment (KIE) software and curricula proposed that scaffolding in the form of reflection prompts can help students to be autonomous integrators of their knowledge. The findings show that self-monitoring prompts, which encourage planning for and reflection on activities, help students demonstrate an integrated understanding of the relevant science; while activity prompts, which guide the inquiry process, are less successful in prompting knowledge integration. Davis and Miyake (2004) further explored scaffolding in classroom but found that there are still lots of areas left for investigation, which include how scaffolding would differ in different communities with different contexts and goals.

Research on technology-enhanced inquiry environments (Kim, Hannafin, & Bryan, 2007) suggested that well-designed computer tools, coupled with scaffolding from experts, teachers, peers, and community members, can support students' thinking and learning about scientific content and processes. It is therefore important to have a better understanding of the relationships between and among factors likely to influence the use and effectiveness of technology tools during science inquiry, together with the modes of inquiry-based instruction that are designed by teachers (Keys & Bryan, 2001).

Hence, inquiry learning should be understood as an integrated approach with equal emphasis on products and practices, and also on content and skills in classroom teaching and learning. Again, there are many discussions on modes of inquiry learning, but few have sufficient and concrete illustrations of how inquiry learning is supported and implemented in classroom. This study endeavors to fill this gap and to provide more substantial understanding of how to create RBLEs with an integrated approach and the learning process.

**Aim and objectives of the study**

This study is a collaboration project between the Hong Kong Education City[4], the Hong Kong Institute of Education, and local primary schools. It aims to provide teachers with a RBLE to help primary learners develop knowledge of the Earth's movement, a relevant topic in the upper primary school curriculum. To achieve this, the first objective of the study is to establish an RBLE by creating both virtual and authentic contexts, selecting appropriate resources, designing relevant tools, and adopting necessary scaffolds. The second objective takes the recommendation of Olkinrora, Mikkila-Erdmann and Nurmi (2004) to move the research focus in multimedia research towards a more process-oriented case research, rather than comparative and effective research, to better understand the effect of using the RBLE in different classroom settings and with varied teaching strategies. Analysis of observed lessons, a comparison of the pre-lesson and post-lesson tests of learners, and also of the responses in post-lesson interviews of learners, teachers' written reflections after all the lessons will be employed to better answer the following research questions.

1. How to design contexts and tools, select resources, and create scaffolds to assist primary learners

in constructing understanding of the Earth's movement?

2. Does the RBLE work equally well for higher and lower performing learners?
3. Does the RBLE work more effectively in instructional settings with less teacher-directed inquiry learning?

## Design of the resource-based learning environment of the Earth movement

### *Creation of contexts to establish RBLE*

The context referrs to where and how the learning is situated. The usual expected learning outcomes of the topic "The Earth's Movement" are the concepts of the Earth spinning and its direction of spinning, the cycle of day and night, the length of a day, time lag, the tilt of the Earth, the relationship between the Earth's revolution and the four seasons, and the change of climate during the four seasons. However, it is difficult to conceptualize the movement of the planet we live on. Learners can only attempt to understand the Earth's movement through the teacher's explanation, an illustration or demonstration, and by viewing figures and diagrams which require imagination that is often beyond the capability of students at primary level.

This RBLE exposes learners to a world beyond the confines of the classroom, which virtually expands the classroom and broadens the perspective of learners on the topic. The RBLE with both virtual and authentic settings helps learners achieve understanding through interaction with the resources.

### *Selection of resources to establish RBLE*

Due to its increasing availability and accessibility, the Web has become one of our major resource bases. However, not all of the information that is found on the Web is accurate, appropriate, and useful. Hence, a piece of Web information has to be carefully evaluated prior to its integration into an RBLE based on its accuracy, relevance, and degree of difficulty with reference to average student ability and the specific subject area. The information objects represented in this RBLE are both static and dynamic. The dynamic resources which undergo changes chosen for this RBLE illustrate daytime in Hong Kong and nighttime in New York with real time scene for better understanding of day and night simultaneously on opposite halves of the globe (Figure 1). The resources of stable contents within the RBLE consist of an authentic time-zone search on an official observatory website to identify the time lag between places in the World (Figure 2).

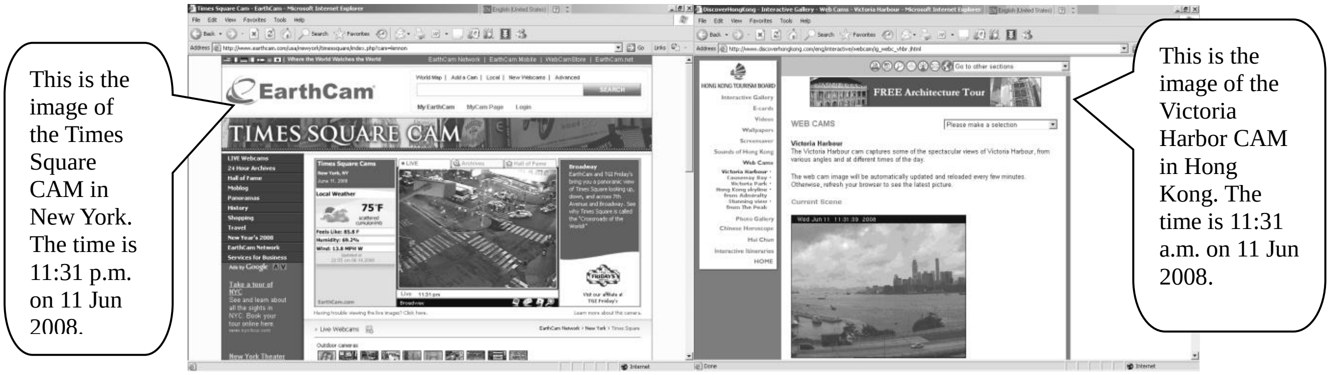



Figure 1. Webcams that show real-time scenes at different places in the world (New York and Hong Kong) which have 12 hours difference.

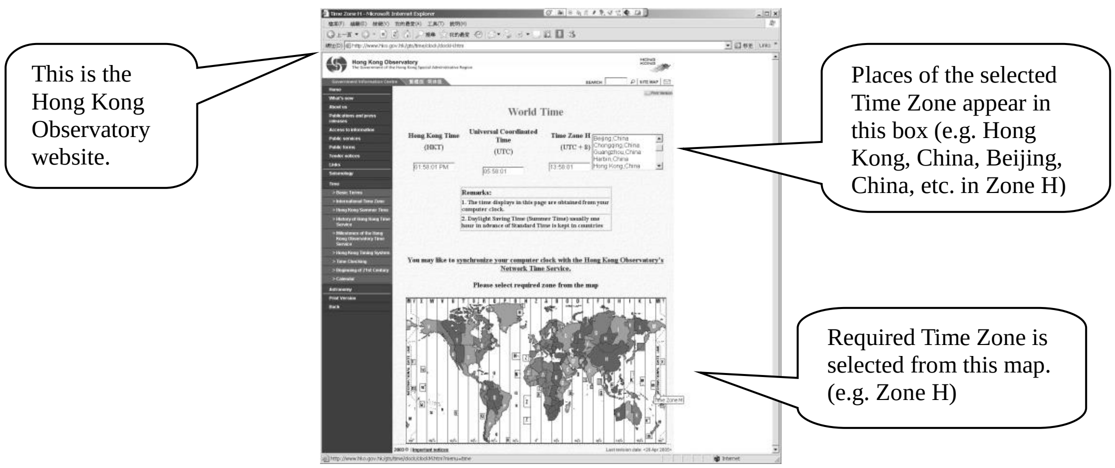



Figure 2. Search for time lag at the Hong Kong Observatory website.

There are other static resources, such as the manipulative videos to assist students in understanding the direction of the Earth's spin by pressing buttons to show videos of different Earth spin directions (Figure 3), and manipulative animations to compare direct and indirect sunlight of the seasons (Figure 4). Learners are required to actively interpret the resources they come across in the RBLE and to associate different resources to gain deeper understanding of the topic (Hannafin, 1997).

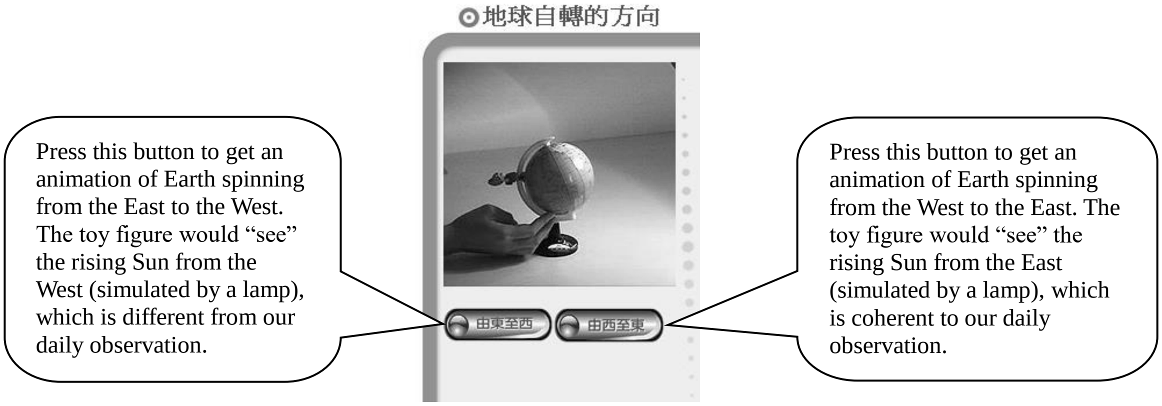



Figure 3. Videos for identifying the direction of the Earth spin.

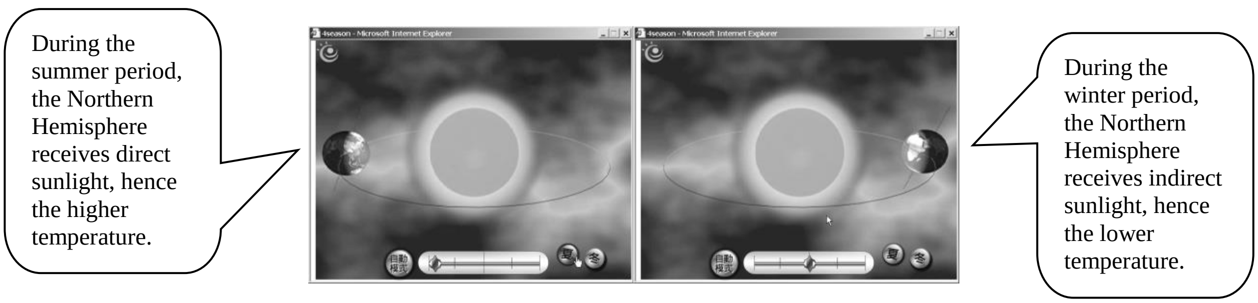



Figure 4. Manipulative animations that compare direct and indirect sunlight of the seasons.

### *Design of tools to establish RBLEs*

Inquiry questions, guidelines for carrying out investigations, charts for filling in data, and the activity book recording of observations and information, are included as the design of tools and scaffolding to facilitate learners in an inquiry by using resources for conceptualization. The tools served dual purposes of processing (providing cognitive support) and manipulating (for testing beliefs or theories).

For example, the table (Figure 5) for recording the time of sunrise in consecutive days helps learners manipulate data to understand “What is the meaning of a day?” and to communicate their work to others.

| Date | Time of sunrise | Difference (hrs) |
|---|---|---|
| Day 1 | | |
| Day 2 | | ________ |
| | | ________ |
| | | ________ |
| | | ________ |
| | | ________ |
| | | ________ |

Figure 5. Tools for learners to record the time of sunrise in a week for understanding "What a day is".

The following is another example from the activity book (Figure 6) that guides learners to search and record information from the Hong Kong Observatory website which would lead to a better understanding of the world time zones.

From the Hong Kong Observatory website:

- Which time zone does Hong Kong belong to? ___________________
- Which countries or places have the same time-zone as Hong Kong? __________________
- What are the time lags of the following places with Hong Kong?

| Hong Kong | Other places | Difference in Hours (Time Lag) |
|---|---|---|
| | I | |
| | R | |

Figure 6. Tools for guiding learners to search and record data for understanding time lag.

***Adoption of scaffolds to establish RBLE***

With reference to Donovan and Bransford's (2005) three fundamental and well-established principles of learning: Principle #1-engaging prior understanding; principle #2–the essential role of factual knowledge and conceptual frameworks in understanding; principle #3-the importance of self-monitoring, a scaffold of inquiry learning is adopted in this RBLE with "Asking and Discussing", "Searching and Selecting", "Doing and Observing", and "Summarizing and Conceptualizing".

For "Asking and Discussing", learners are encouraged to read the inquiry questions when they start using the RBLE, to ask themselves questions, to become capable of accessing their prior understanding of the topic, and to discuss among peers or with the teacher. For "Searching and Selecting", learners need to search through related resources and tools for explanations and answers to the questions. “Doing and Observing” encourages learners to work with both real and virtual resources or tools to acquire a better understanding of related phenomenon. “Summarizing and Conceptualizing” encourages learners to make generalizations and construct conceptualization from the information acquired in previous scaffolds. In addition, “Extended Inquiry” and “Think More” are also provided as extended work for learners beyond normal lesson time.

**Experimental setup and data sources**

The RBLE of the Earth’s movement was implemented in four classes, at the same level, at a local primary school. The four classes involved had a total of 128 primary students with ages between 11 and 12 years. The students were originally assigned to different classes based on their academic performance in the previous years: two classes of higher performing students (Classes H1 and H2) and two classes of lower performing students (Classes L1 and L2). This is a common practice in local schools and the research team found this an optimal opportunity to study the aptitude-treatment interaction (Snow, 1998) between students’ academic performance and the choice of instructional setting/strategy for the use of RBLE. There was a hypothesis that the effects of understanding the Earth’s Movement depend on the interaction between students’ academic performance and classroom setting. This prepared the way for a two by two analysis of RBLE use of student ability.

The students were pre-tested before the start of the learning unit to have a measure of their prior understanding of the Earth movement. There were ten questions with multiple choices with seven of them requiring written explanations (The test is attached in the appendix). Learners are required to work on an identical post-lesson test upon completion of the multimedia unit to measure their learning outcomes.

The research team met the four teachers who were involved in the research a few times in advance to discuss the aim and objectives of the research, and to determine the two possible settings for using the multimedia unit for teaching and learning, the classroom setting and computer room. This is the common infra-structure of local schools to have at least one computer room with sufficient computer terminals for a class of students to work on-line, and all classrooms are equipped with one teacher computer with screen projection in the front of the classroom.

Classes H1 and L1 were arranged to have the lessons in a classroom setting. The teachers of these 2 classes used their computers with the RBLE with the same student activity books and teacher guidebook to ensure that the teachers are using the same strategies in their teachings. Classes H2 and L2, meanwhile, were arranged to have lessons in a computer room setting with groups of two to three students working on one computer. All teachers were reminded to follow the scaffold flow of the RBLE precisely with teachers as facilitators, and lesson observations were conducted by the research team to make sure the teachers followed the instructions. Each individual student was provided an activity book which included the scaffolds. Each class took approximately four lessons at 35 minutes each (a total of about 140 minutes) in a week, during which they covered a whole unit of RBLE on the Earth's movement.

There were different data sources to fulfill the objectives and answer the research questions. The students' pre-lesson and post-lesson test results were collected and compared statistically by using t-tests and ANOVA to examine the learning outcomes. Also, a detailed analysis of the written responses on the tests was carried out to determine the changes in students' understanding of the Earth's movement. The comparison of time duration of the different activities conducted in the four classrooms was studied with the analysis of the video-taped lessons. Twelve students, three from each of the four classes, were interviewed after lessons to express their views on three aspects. Firstly, students were asked to describe the multimedia components they had worked with the Earth RBLE; secondly, students were invited to describe the most useful/helpful part of the Earth RBLE; and thirdly, students were encouraged to reflect on the influence of the use of the RBLE on their understanding of the Earth's movement. The audio records of interviews were analyzed to capture the general views of students toward learning with multimedia resources. Lastly, the four teachers involved in the teaching were invited to describe their reflections after all the four lessons to better understand the actual learning and working processes with the RBLE, as well as the factors affecting the learning outcome.

## Results and discussions

### ***The learning processes with the RBLE***

In the classroom setting, the teachers used the teacher's computer to show the multimedia resources and information on the screen, following the scaffolds required by the RBLE of the Earth movement. The teachers also occasionally invited students to work on the teacher's computer for demonstrations, illustrations, and explanations on the multimedia resources. For example, students were invited to work on the teacher's computer to search for information about different time zones to identify time lags with local time, while the rest of the class observed, discussed among themselves, and responded to the inquiry questions designed in the RBLE. The time used by the teacher to show the resources for introductions and explanations was shown on Table 1. The rest of the lessons were generally teacher-student interactions in responding to the inquiry questions.

In the computer room setting, the teacher worked on the teacher's computer, while the students worked in groups of two to three on other computers with the RBLE of the Earth movement and activity book. Similar to the classroom setting, the teacher followed the scaffolds required by the RBLE, but the difference was that the students were encouraged to click on the components of the multimedia unit for observation and reading, to discuss among themselves and to respond to the inquiry questions. Students were encouraged to record the response on one's own activity book. Generally, students were free to work at their own pace with each component within a time limit assigned by the teacher. However, the teacher, occasionally, used the MUSE system (a classroom control system com content delivery system for teacher's easy control of digital content) to interrupt the work of students when students had difficulty accessing websites or web information. Besides, the teacher also used the MUSE system to focus students' attention to the display of search results or the work from particular groups of students.

The analysis of all videotaped lessons was focused on the use of multimedia resources by the students and the teacher, and on the interactions and discourses between the students and the teacher. With reference to Martin-Hansen's (2002) notion of open, guided and coupled inquiry, the learning and work processes could be generally classified into two approaches: teacher-regulated inquiry learning and interactive inquiry learning.

*Teacher-regulated inquiry learning.*

The teacher-regulated inquiry learning included the teacher presenting multimedia resources or other resources for introduction and explanation, to facilitate students' responding to the inquiry questions. For example, in the activity of data search for the times of sunrise and sunset from the Hong Kong Observatory website, the teacher provided the pdf file of the times of sunrise and sunset from the Hong Kong Observatory website, the students read the data, and recorded the related data on their activity book. The teacher conducted this task step-by-step in a more teacher-regulated way to ensure students acquired the relevant information from the web resources.

*Interactive inquiry learning.*

The interactive inquiry learning comprised of the teacher interacting with the students using the resources, the students working with multimedia resources themselves, and the students working on hands-on activities introduced in the Earth RBLE. Some examples of the teacher interacting with the students using the resources were: the use of the Hong Kong Observatory website to find the time lag of places in different time zones (Figure 2), and the use of two video clips (one video clip illustrates the Earth is rotating from the West to the East, and the other video clip illustrates the Earth is rotating from the East to the West) to identify the correct direction of the Earth's spin (Figure 3). Examples of the students working with multimedia resources by themselves included: using webcams to identify day and night in different parts of the world (Figure 1), undertaking hands-on activities, recording observations and data located from the resources onto the activity book, and using a torch and globe to determine the movement of the earth. Below are vignettes of the interactive inquiry learning (Figure 7).

| **Interactive inquiry learning** | **Tasks** | **Interaction or discourse between the teacher and the learners** |
|---|---|---|
| Teacher using resources for interaction with students | The use of two video clips to identify the direction of the Earth's spin | Teacher: "Look at the video, the toy figure is now facing North, what are his two arms pointing to?"<br>Student 1: "His right arm is pointing to the East."<br>Student 2: "His left arm is point to the West."<br>Teacher: "If the Earth spins westward, from which direction does the toy figure see the Sun?"<br>Student 3: "On his left-hand side."<br>Teacher: "Where does he observe the rising of the sun? East or West?"<br>All students: "West!"<br>Teacher: "Is the sun rising in the West? Is the phenomenon we observed of the Earth spinning eastward the same as what we observe daily?"<br>All students: "Not the same."<br>Teacher: "Then you should watch the other video to see if the Earth spinning eastward is the same phenomenon that we can observe everyday." |
| Students working with multimedia resources themselves | The use of webcams to identify day and night in different parts of the world | Student 1: "New York and Hong Kong have the same time!"<br>Student 2: "They are all 3:12."<br>Student 3: "No, look at the corner, New York is 3:12 a.m. but HK is 3:12 p.m."<br>Student 2: "The time is the same!"<br>Student 1: "But the two places differed by 12 hours." |

Figure 7. Vignettes of interactive inquiry learning.

Table 1 shows the time allocation of the different activities recorded in all lessons of the four classes. It could be observed from the time allocation of the different activities, that both classes conducted in the classrooms had more teacher-regulated activities (about one third of the lesson time) than the classes conducted in the computer rooms (less than a quarter of the lesson time). If two classes conducted in the computer room with students working in groups were compared, more time (one-fifth of the lesson time) was spent on teacher-regulated activities for the class with lower performing students. This observation reflected that more teacher-regulated activities were required for the class with lower performing students in inquiry with the Earth RBLE. This implied that students in the classroom setting and lower performing students were allowed fewer opportunities to engage and interact with the RBLE, However, it might be argued that student inquiry was not facilitated under the teacher-regulated RBLE.

Table 1. Time allocation of the different activities conducted in the four classes.

| Class | Academic background of students | Classroom setting | Total lesson time | Teacher-regulated Inquiry learning | Interactive inquiry learning with teacher-student and student-student interactions | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Teacher showed the resources for introductions and explanations | Teacher-student interaction | Students worked with resources themselves | Students' hands-on activities | Other |
| H1 | Higher performing | Classroom | 126 minutes | 33% | 27% | 10% | 18% | 12% |
| L1 | Lower performing | Classroom | 135 minutes | 34% | 25% | 14% | 16% | 11% |
| H2 | Higher performing | Computer room | 135 minutes | 13% | 38% | 30% | 12% | 7% |
| L2 | Lower performing | Computer room | 124 minutes | 22% | 42% | 20% | 7% | 9% |

### *Learning outcomes*

The learning outcomes of students were measured through a statistical analysis of their pre-lesson and post-lesson tests, with a reliability of 0.622. The statistical analysis of the achievement of the 4 classes of students was viewed from the following perspectives. First, a comparison of the achievements of the pre-lesson and post-lesson tests of the same classes of students. Second, the interaction effect of academic background and instructional settings on students' achievement. Third, the level of understanding by students was identified from an analysis of responses in the pre- and post-lesson tests.

*a. The learning outcome of students from the pre- and post- lesson tests comparison*

The pre- and post-lesson tests of students in each class were compared statistically to identify the differences of their learning outcomes (Table 2 and Table 3). With reference to the means of pre- and post-lesson tests of the four classes, though there were increases in the means, the statistical values reflected that students were not necessarily successful in their learning with an RBLE of the "Earth's Movement".

For class H1 (higher performing students who studied in a classroom), there was a minor but significant difference (T= 2.036*), which indicated a small change in the learning outcome of the Class H1 students after the lessons. For class H2 (higher performing students who studied in a computer room), there was a significant difference (T= 6.019***), which indicated that a considerable improvement in the learning outcomes of the students.

For class L1 (lower performing students who studied in the classroom), the significant difference (T= 3.363**) indicated that an improvement in the learning outcomes of the students and that the changes were substantial. For Class L2 (lower performing students who studied in the computer room), no statistically significant difference was found.

Table 2. Mean, standard deviation and paired t-test of the pre-lesson and post-lesson test measures of higher performing students in classroom and computer room setting

| Class | Numbers of students | Pre-lesson test | | Post-lesson test | | Paired t-test | |
|---|---|---|---|---|---|---|---|
| | | Mean | (S.D.) | Mean | (S.D.) | | |
| H1 | 36 | 12.028 | (3.317) | 12.861 | (2.295) | 2.036* | t(35) |
| H2 | 37 | 11.73 | (2.825) | 14.946 | (2.235) | 6.019*** | t(36) |

Table 3. Mean, standard deviation and paired t-test of the pre-lesson and post-lesson test measures of lower performing students in classroom and computer room setting

| Class | Numbers of students | Pre-lesson test | | Post-lesson test | | Paired t-test | |
|---|---|---|---|---|---|---|---|
| | | Mean | (S.D.) | Mean | (S.D.) | | |
| L1 | 28 | 9.25 | (2.633) | 10.893 | (2.499) | 3.363** | t(27) |
| L2 | 27 | 9.519 | (3.03) | 10.407 | (2.188) | 1.63 | t(27) |

*b. The learning outcomes of students with comparable academic backgrounds and/or instructional settings*

In the ANCOVA, post-lesson test measure was adjusted by removing the effect of pre-lesson test. The adjusted post-lesson test measure was then used for comparing whether there was difference in gain of students' understanding if all students had the same pre-lesson measure. There is significant main effect of students' academic background (F= 35.427***), instructional setting (F= 4.800*), as well as the interaction effect of students' academic background and instructional setting used (F= 14.183***). Both the original and adjusted post-lesson test measures comparing different academic background and settings are presented in Figure 8.

The results of this analysis support that the level of students' understanding and the gain of their understanding about Earth's movement depends on students' academic background as well as the instructional setting in the learning environment. It could be observed that even in the same RBLE, higher performing students benefited more from a learning environment with a less teacher-regulated approach and working in groups in the computer room, whereas lower performing students benefited more from the teacher-regulated approach in the classroom.

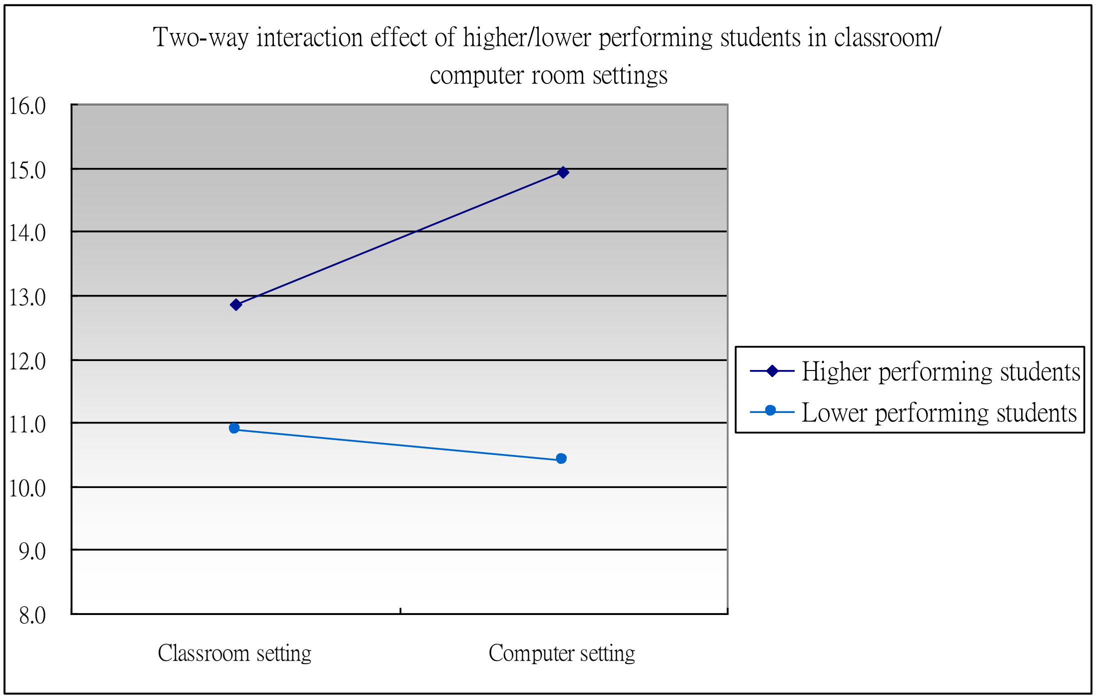



Figure 8. Post-lesson test scores comparing the classes with different academic background and/or settings

*c. Level of students' understanding.*

From the analysis of the questions in the pre- and post-lesson tests, students were found to have attained a substantial conceptual understanding of the "Earth's Movement" (Figure 8).

Question 1a: Is it day-time all around the world at this moment?

| Pre-lesson test | Post-lesson test |
|---|---|
| ☐ yes<br>☑ no<br>Explanation: "it is because some places are facing the Sun while other places are facing the moon"<br>***(Right choice but wrong explanation)*** | ☐ yes<br>☑ no<br>Explanation "it is because of the earth's spinning"<br>***(Right Choice and acceptable explanation)*** |

Question 3: In Hong Kong, is the length of daytime throughout the year the same? Why?

| Pre-lesson test | Post-lesson test |
| --- | --- |
| ☐ yes, the length of daytime throughout the year is the same<br>☐ no, the daytime is longer in winter<br>☑ no, the daytime is longer in summer<br>Explanation:<br>***(Right choice but no explanation)*** | ☐ yes, the length of daytime throughout the year is the same<br>☐ no, the daytime is longer in winter<br>☑ no, the daytime is longer in summer<br>Explanation: "no, it is because Hong Kong receives sunlight differently at different times of the year"<br>***(Satisfactory explanation)*** |

Question 4: A flight takes off at 8a.m from Hong Kong to Seoul. According to the Korean time, when should the plane arrive if the flight takes 3 hours? Why?

| Pre-lesson test | Post-lesson test |
| --- | --- |
| ☐ 10 a.m. ☐ 11 a.m.<br>☐ 12 a.m. ☑ 1 p.m.<br>Explanation: the time of different places are different<br>***(Inaccurate choice and explanation)*** | ☐ 10 a.m. ☐ 11 a.m.<br>☑ 12 a.m. ☐ 1 p.m.<br>Explanation: it is because Korea is one hour ahead of Hong Kong<br>***(Correct choice and explanation)*** |

Figure 8. Changes in the responses of students of the same question in pre- and post-lesson tests.

### *Students' views towards inquiry learning with multimedia resources*

The student interview analyses were used to capture the general views of students toward inquiry learning with multimedia resources. It was found that students of varied abilities all managed to list all of the multimedia components (the webcams of day and nights, websites of the time lag, the sunrise and sunset time; and animations and videos of the earth movement) selected for use in the Earth RBLE with comments of "attractive" and "interesting". This revealed that a wide variety of multimedia resources and tools would make the RBLE attractive to students. However, students who worked in the classroom and lower performing students who worked in the computer room claimed that they did not have the chance to work with these resources. It was because the resources were used by the teacher in the classroom and by other group members in the computer room respectively.

With regard to the most useful/helpful parts of the RBLE, the responses from students mainly rested on the following: a) multimedia resources and tools, and b) interactions during inquiry learning. The multimedia resources and tools students found useful/helpful included the animations for the understanding of the Earth's revolutions, websites for the search of answers and explanations, the map of a website and animations for the knowledge of time lag, and videos that showed the direction of Earth spin. The only distinction that could be identified from students who are of varied ability and from different classroom settings was the fewer opportunities the students could work with these multimedia resources in the classroom setting. The interactions during the lessons that impressed students most were the discussion with other group members, the demonstration of work by other students, the explanation of one's views, the hands-on activities to determine the direction of the Earth's spin, and the use of activity book to record what they had observed and discovered. Yet, the lower performing students who had worked in the computer room expressed concerns about less teacher input in their learning with this Earth RBLE.

All students recognized that the creation of context in this RBLE helped them to improve their understanding of the Earth's movement. On one hand, all higher performing students were able to explain clearly the phenomena, such as the formation of the four seasons, and the direction of the Earth spin and Earth revolution during the interviews. This understanding was mainly gained from the clear and lively illustrations provided by the multimedia resources and the opportunities for students to work with these resources. On the other hand, the lower performing students seemed to be able to describe the phenomena, but what they described was not easily deciphered. Besides, the concept knowledge about the Earth's movement delivered through multimedia resources was much more informative than that in textbooks. A few higher performing students even responded that the activity book, the design of tools for this RBLE, guided them to record what they had observed from the multimedia resources, and this made learning more effective. However, the three lower performing students expressed their worries and fear of less talk and fewer answers from the teacher during these 'experimental lessons' as described by the students, which were quite different from the other regular lessons.

***Teachers' views towards inquiry learning with multimedia resources***

The analysis of teachers' written reflections after the lessons showed that teachers could identify some valuable observations which are contributing to the future use of RBLEs. First is the benefit to learning with the use of multimedia resources; second is the difficulty encountered by the students, in particular the lower performing students, when using the multimedia resources with inquiry learning in the assigned settings, and what teachers did to help students overcome the difficulties; third is the changes and modification teachers proposed in the future planning of using the multimedia resources.

With stimulations from the multimedia resources of the Earth movement and the scaffolds of inquiry learning adopted in the RBLE, students' intense participation and active interactions were reported by the four teachers. This effected in motivating students' interest in learning, enhancing students' eagerness to respond to the inquiry questions, and elevating students' ability in explaining the phenomenon by themselves. Teachers also found that the viewing and working with multimedia resources facilitated students' thinking and learning of abstract concepts of the Earth movement. Besides, teachers also recognized that students' experiences in working with the multimedia resources and the extended questions in the “Think More” of Earth RBLE were useful and motivated for students to further their work and learning after lesson.

Almost all of the teachers reported a slightly uncomfortable feeling in using the Earth RBLE. It was because of the many more dynamic resources than the textbook teachers commonly used. Pedersen and Liu (2003) had similar observation that teachers’ implementation of technology-enhanced student-centered learning environments (SCLEs) is affected by their beliefs about effective practices. Research findings show that teachers are more likely to use student-centered programs in ways consistent with the designers’ intentions if these programs are designed with their beliefs in mind. Teachers also reported their observation of vulnerability among students who were of average academic background during lessons. These students were previously relied on answers provided by the teachers, rather than inquiring into information to find answers and explanations for the questions. The teachers who used the Earth RBLE in the classroom setting also expressed difficulty in allowing all students in the class to read the details of the websites from the screen. Teachers teaching in the computer room settings were concerned about the ability of students to complete the tasks by themselves, which demanded more cognitive effort and collaboration with peers.

The changes and modifications suggested by teachers in their future planning of RBLEs were a preparation of printed copies of web materials from the RBLE. This is to improve the involvement of learners in the inquiry learning process in a classroom setting. What can be envisaged for more structured resources for these students is the “print-on-demand” suggestion in the teacher’s guide, reminder or suggesting teachers to make necessary copies for students’ careful reading and observation of information. In addition, teachers also suggested arranging students into groups of two or three, to aid discussion and to cooperate on assigned tasks in the Earth RBLE, even in a classroom setting with no student computer facilities available.

## Conclusions

### *Importance of instructional approaches in using the RBLE*

The creation of context, the selection of resources, the design of tools, and the adoption of scaffolds of the Earth RBLE in this study were designed to support learners to construct a conceptual understanding of the Earth’s movement. The different degree of students’ achievement reflected from the different levels of significance obtained in the statistical analysis, indicated the fundamentally different effects of instructional approaches of inquiry and classroom settings to students’ understanding of the “Earth Movement” with the same RBLE. This aptitude treatment interaction of academic background and instructional setting echoed the views of Olkinrora, Mikkila-Erdmann and Nurmi (2004), as well as that of Kim, Hannafin and Bryan (2007) that the use of multimedia materials alone do not guarantee or produce high-quality learning because they do not magically benefit all learners equally. Instead, the quality of the pedagogical design of the multimedia materials and the way in which instruction is implemented are the most important, not the technology that is applied in the multimedia materials themselves. Furthermore, as suggested by Sharma and Hannafin (2007) in their discussion of the role of scaffolding in technology-enhanced learning environments (TELEs), scaffolds may provide opportunities for students to deepen their understanding by externalizing and comparing their knowledge and beliefs with those of peers and experts, thus the design of effective scaffolding requires consideration of a learner's ability to interact with and use scaffolding tools.

***Integrated use of inquiry approaches with students of different academic background***

The analysis of the learning and teaching processes in different classroom settings resulted in a classification of two instructional approaches, the teacher-regulated inquiry learning and the interactive inquiry learning. The main task identified as the teacher-regulated inquiry learning was simply the teacher introducing multimedia resources or other resources for eliciting students' thinking and responses, but with limited opportunities for student to work with the RBLE. And the main tasks classified as interactive inquiry learning were the teacher demonstrating and interacting with students using the multimedia resources and students working with multimedia resources themselves. The integrative use of these two approaches in the different classroom settings in this study brought out the importance of an integrated inquiry approach which comprises all of teacher regulation; teacher-learner interactions, and learner-learner interactions and learner-material interactions, in varied degree of use in different classroom settings and with students who are of different academic backgrounds. These results may provide insights for teachers to use multimedia resources more effectively with-in their daily teaching, and helps to shed light on how coupled inquiry which combined a guided investigation and open investigation as suggested by Martin-Hansen (2002) function in primary classrooms.

***Lack of students' readiness for inquiry learning***

Teachers' observation of students' vulnerability with the interactive inquiry learning approach, the concerns raised from the highly performing students that the multimedia resources were less concrete and substantial than the textbook, and the reporting of concerns from lower performing students about less teacher input in their learning with the multimedia resources in this study, are of particular importance. A similar situation was indicated by Case (2003) that learners who were accustomed to didactic instructions often lacked confidence and were uncomfortable with a resource-based learning environment. This is a result worth noting for teachers in designing inquiry learning and it is also of great significance for researchers in their further study of students' readiness to inquiry learning. The occasional invitation of students to work on the teacher's computer, and preparation of printed copies of web materials for group discussion, were the solutions used and suggested by teachers in this study, to achieve better teacher-student, student-student and student-material interaction in the teaching and learning process (Kim, Hannafin, & Bryan, 2007). This was a move towards a more guided approach in the inquiry learning process notwithstanding the limitation of classroom settings that did not have sufficient computers for students to work on.

Last but not the least, it could be concluded that the findings of this study raises the challenge for making RBLEs more effective for lower performing students, and hence an understanding of the integrated approach to inquiry learning, with equal emphasis on teacher-regulations and interactions, is recommended in future use of RBLEs. This is to supplement the views of Abell and McDonald (2004) of an integrated approach of products and practices, and also of content and skills in inquiry learning, which is an important consideration for teaching and learning science with internet and resource-based learning environment. Furthermore, it is necessary to address Pea's (2004) concern to prove how the software design serves to advance a learner's performance beyond what they would have worked alone in its use to scaffold complex learning.

**Notes**

1. http://www.cst.cmich.edu/users/kiefe1we/thoma1im/pub_html/AstroGeo.htm
2. http://www.kidseclipse.com/pages/a1b3c1d1.htm
3. http://www.bbc.co.uk/schools/scienceclips/teachersresources/ages9_10/tr_earth_sun_moon_offlp.shtml
4. Hong Kong Education City, a wholly-owned subsidiary of the Education and Manpower Bureau, is responsible for managing the Hong Kong Education City (HKedCity) website and also for upholding the mission of promoting quality education and Information Technology education in Hong Kong. The website aims to provide quality one-stop education portal and resources for teaching and learning in Hong Kong.

**References**

Abell, S. K., & McDonald, J. T. (2004). Envisioning a curriculum of inquiry in the elementary school. In L.B. Flick & N.G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 249-261). The Netherlands: Kluwer Academic Publishers.

Alvarado, A. E., & Herr, P. R. (2003). *Inquiry-based learning using everyday objects*. Thousand Oaks, CA: Corwin Press, Inc.

Bakas, C., & Mikropoulos, T. A. (2003). Design of virtual environments for the comprehension of planetary phenomena based on students' ideas. *International Journal of Science Education*, *25*(8), 949-967.

Barab, S. A., Hay, K. E., Barnett, M., & Keating, T. (2000). Virtual solar system project: Building understanding through model building. *Journal of Research in Science Teaching*, *37*(7), 719-756.

Blumenfeld, P., Fishman, B. J., Krajcik, J. S., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149-164.

Brewer, W., & Vosniadou, S. (1990). A cross cultural investigation of children's conceptions about the Earth, the Sun and the Moon: Greek and American data. In H. Mandl, E. DeCorte, N. Bennet, & H. F. Friedrich (Eds.), *Learning and instruction: European research in an international context* (pp. 605-629). Oxford: Pergamon.

Brewer, W., & Vosniadou, S. (1994). Mental models of the Daylight Cycle. *Cognitive Science*, *18*, 123-183.

Case, R. (2003). Making critical thinking an integral part of electronic research. *School Libraries in Canada, 22*(4), 13-16.

Coleman, E. B. (1998). Using explanatory knowledge during collaborative problem solving in science. *Journal of the Learning Sciences, 7*(3&4), 387-427.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of*

*Research in Science Teaching, 37*(9), 916-937.

Curriculum Development Council (2002). *General Studies for primary schools curriculum guide (Primary 1-Primary 6)*. Hong Kong: Printing Department.

Davis, E., & Linn, M. C. (2000). Scaffolding students' knowledge integration: Prompts for reflection in KIE. *International Journal of Science Education, 22*(8), 819-837.

Davis, E. A., & Miyake, N. (2004). Explorations of scaffolding in complex classroom systems. *Journal of the Learning Sciences, 13*(3), 265-272.

Donovan, M. S., & Bransford, J. D. (2005). *How students learn: history, mathematics, and science in the classroom.* Washington, DC: National Academies Press.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*(3), 355-385.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences, 8*(3-4), 391-450.

Ferdig, R. E., Mishra, P., & Zhao, Y. (2004). Component architectures and web-based learning environments. *Journal of Interactive learning Research, 15*(1), 75-90.

Gilbert, J. K. (2000). Editorial: The knowledge integration environment: A preface. *International Journal in Science Education, 22*(8), 779.

Glynn, S. M., Yeany, R. H., & Britton, B. K. (1991). A constructive view of learning science. In S.M. Glynn, R. H. Yeany, & B. K. Britton (Eds.), *The psychology of learning science* (pp. 3-19). Hilldale, NJ: Lawrence Erlbaum Associates.

Hannafin, M. J. (1997). *Resource-based learning environments: Methods and models*. Paper presented at the Australasian Society for Computers in Learning in Tertiary Education ASCILITE 1997 Conference, Perth, Australia.

Hill, J. R., & Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. *Educational Technology Research and Development, 49*(3), 37-52.

Hover, S. V., & Horne, M. V. (2005). Whole-class inquiry: Social studies. *Learning and Leading with Technology, 32*(8), 49-51.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Kim, M., Hannafin, M. J., & Bryan, L. (2007). Technology-enhanced inquiry tools in Science Education: An emerging pedagogical framework for classroom practice. *Science Education, 96*(6), 1010-1030.

Kitazawa, T., Nagal, M., Kato, H., & Akahori, K. (2005). Development and assessment of the "Science Net" e-Learning system for science education at the Elementary school level. In C. K. Looi, D. Jonassen, & M. Ikeda (Eds.), *Towards sustainable and scalable educational innovations informed* *by the learning sciences: Sharing good practices of research, experimentation and innovation* (pp. 740-743). Singapore: APSCE.

Land, S., & Hannafin, M. J. (2000). Student-centered learning environments. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 1-23). Mahwah, NJ: Erlbaum.

Linn, M. C. (2000). Designing the knowledge integration environment. *International Journal of Science Education*, *22*(8), 781-796.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education*, *87*(4), 517 – 538.

Jones, B., & Lynch, P. (1987). Children's conceptions of the Earth, Sun and Moon. *International Journal of Science Education*, *9*(1), 43-53.

MacGregor, S. K., & Lou, Y. (2004). Web-based learning: How task scaffolding the web site design support knowledge acquisition. *Journal of Research on Technology in Education, 37*(2), 161-175.

Martin-Hansen, L. (2002). Defining inquiry. *The Science Teacher, 69*(2), 34-37.

Morris, P. (1995). *The Hong Kong school curriculum: Development, issues and policies*. Hong Kong: Hong Kong University Press.

Mistler-Jackson, M., & Songer, N. B. (2000). Student motivation and internet technology: Are students empowered to learn science? *Journal of Research in Science Teaching, 37*(5), 459-479.

Oliver, K., & Hannafin, M. J. (2001). Developing and refining mental models in open-ended learning environments: A case study. *Educational Technology Research and Development, 49*(4), 5-33.

Olkinrora, E., Mikkila-Erdmann, M., & Nurmi, S. (2004). Evaluating the pedagogical value of multimedia learning materials: An experimental study in primary school. In N. M. Seel & S. Dijkstra (Eds.), *Curriculum, plans, and processes in instructional design: International perspectives* (pp. 331-352). Mahwah, NJ: Lawrence Erlbaum.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences, 13*(3), 423-451.

Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development, 51*(2), 57-76.

Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments*, *15*(1), 27-46.

Sneider, C., & Pulos, S. (1983). Children's cosmographics: Understanding the earth's shape and gravity. *Science Education*, *67*(2), 205-222.

Snow, R. E. (1998). Abilities as aptitudes and achievements in learning situations. In J. J. McArdle, R.

W. Woodcock (Eds.), *Human cognitive abilities in theory and practice* (pp.93-112). Mahwah, N.J. : L. Erlbaum.

So, W. M. W. (2002). Constructivist teaching in primary science. *Asia-Pacific Forum on Science Learning and Teaching*, *3*(1), Article 1. Retrieved May 22, 2008, from http://www.ied.edu.hk/apfslt/

So, W. M. W., & Kwong, Y. F. (2003). Research on teaching of "Solar Eclipse" in primary classroom. *Asia-Pacific Forum on Science Learning and Teaching*, *4*(2), Article 1. Retrieved May 22, 2008, from http://www.ied.edu.hk/apfslt/

Trumper, R. (2001). A cross-age study of senior high school students' conceptions of basic astronomy concepts. *Research in Science and Technological Education*, *19*(1), 97-109.

Vosniadou, S. (1991). Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies*, *23*(3), 219-237.

Vosniadou, S., Skopeliti, I., & Ikospentaki, K. (2004). Modes of knowing and ways of reasoning in elementary astronomy. *Cognitive Development*, *19*, 203-222.

Wallace, R. M., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the web: Students online in a sixth-grade classroom. *Journal of the Learning Sciences*, *9*(1), 75-104.

Wang, S. K., & Reeves, T. C. (2006). The effects of a web-based learning environment on student motivation in a high school earth science course. *Educational Technology Research and Development*, *54*(6), 597-621.

**Appendix**

Earth Movement

Pre-lesson / Post-lesson Test (translated from Chinese to English)

Name：______________(___)  Class：________  School：____________

Sex：M / F  Age：________  Date：____________

1a. At this moment, is it daytime all around the world?

☐ Yes ☐ No

Your explanation is:_____________________________

1b. Why are there days and nights? It is because …

☐ the Earth moves around the Sun. ☐ the self-spinning of the Earth.

☐ there are clouds blocking the sunlight in the night .

☐ sometimes the Earth is shadowed by the Sun, and sometimes it is not.

Others：____________________________

2a. How long does the Earth take for a rotation?

☐ 1 hour ☐ 1 day ☐ 1 year

2b. How many hours are there in a day?

☐ 12 hours ☐ 24 hours ☐ 36 hours

2b. We can observe the Sun "rises" from the east and "falls" to the west. Does it mean that the Sun moves around the Earth from the east to the west?

☐ Yes ☐ No

Your explanation is：_____________________________

3. In Hong Kong, is the daytime throughout the year the same? Why?

☐ Yes, the daytime throughout the year is the same.

☐ No, the daytime in winter is longer.

☐ No, the daytime in summer is longer.

Your explanation is：____________________________________________

This is the image of the Hong Kong WEB CAM at the Victoria Harbour of



4. A flight takes off at 8a.m from Hong Kong to Seoul. According to the Korean time, when should the plane arrive if the flight takes 3 hours? Why?

☐ 10 am ☐ 11 am

☐ 12 noon ☐ 1 pm

Your explanation is：________________________________________

5a. In December, are all places in the world winter? Why?

☐ Yes

☐ No

Your explanation is ：__________________________

5b. Why are there different seasons in a year?

☐ It is hotter when the Earth is closer to the Sun.

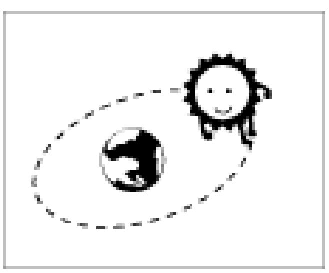
☐ The Sun releases heat and causes different seasons.

☐ The tilt of the earth axis makes some places received direct rays of sunlight and other places received indirect rays.

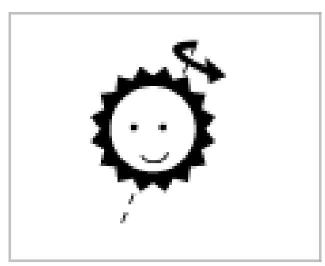
☐ Others：_____________________________________________

Your explanation is：_______________________________________

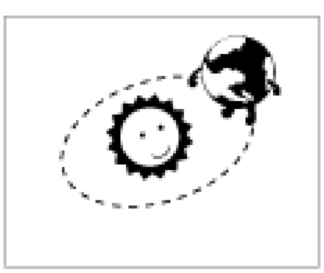
6. Which of the followings about the movement of the Sun and the Earth are correct?
（Please ✓ if it is correct, and X if it is incorrect）



☐ The Sun revolves about the Earth.

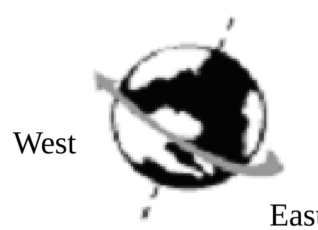


☐The Sun rotates about its axis.



☐ The Earth revolves about the Sun.


☐ The Earth rotates about its axis (From west to east) .




☐ The Earth rotates about its axis (From east to west) .