PROMOTING CONSTRUCTIVIST AND SELF-DIRECTED SCIENCE LEARNING INCORPORATING TECHNOLOGICAL TOOLS: A RESEARCH LESSON IN A SECONDARY SCHOOL CLASSROOM

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Abstract

With the ever-increasing demand in knowledge and technological advancement, much emphasis has been placed on the application of Information and Communication Technology (ICT) in science education. An example could be seen in the increased attention on the use of animation software to stimulate students' interests in science learning. It is believed that the learning of many complicated scientific concepts, principles or theories that could hardly be explained by plain text or 'chalk and talk' may be achieved through visualization using 3-D animation multimedia software. This articles reports on the experiences of the authors in designing a research based science lesson with multimedia integration that was implemented in a secondary school using the lesson study (Yoshida & Fernandez, 2002; Isoda, 2008) or research lesson (Lewis & Tsuchida, 1998) approach. During the '*Lesson Planning*' phase, the use of multimedia as resource materials, 'Novak and Gowin's (1984) metacognitive strategies as well as the five phases of constructivist approaches by Driver and Bell (1986)' as specific steps developed for the lesson were dwelt on in specific. The '*Lesson Presentation*' phase includes a report on the tryout of the Form 4 Physics lesson on 'Energy and Heat' with observation notes by the team members consisting mainly of the science teachers in a local secondary school and the specialists in RECSAM. The most important step in a researched lesson, i.e. '*Lesson Reflection*' was elaborated with an overview of the lesson and a summary of the comments or feedback by the team members who had observed the lesson being carried out. What was learned through this step could be applied in the next lesson study in other science classes with similar focus areas. These would include the suggested concrete alternatives of how the lesson could be improved which would contribute towards developing an in-service model for the Continuous Professional Development (CPD) of science teaching.

Introduction

With the ever-increasing demand for knowledge and the rapid technological advancement in various fields, the application of Information and Communication Technology (ICT) in science education has increasingly caught the attention of curriculum developers and implementers. Major emphasis is placed on the application of technology as tutors, tools or tutees in enhancing teaching-learning activities such as the increased attention on the use of animation software to stimulate students' interests in learning science. It is believed that the learning of many complicated scientific concepts, principles or theories that could hardly be explained by plain text or 'chalk and talk' may be achieved through visualization using 3-D animation multimedia software.

Overview and objectives

This article reports the authors' experience in designing an ICT integrated research-based science lesson that was implemented in a secondary school using the lesson study approach. The lesson was part of a larger research coordinated by the second author that included the conduct of a series of workshops to introduce the EUREKA 3-D animation software to a group of secondary school teachers. In addition, the efforts initiated by the first and third authors to promote science learning via the investigative approach aimed at achieving the following objectives:

- To develop an in-service model for the Continuing Professional Development (CPD) of science teachers based on the research of an ICT-based science lesson using the lesson study approach;

- To explore the use of technological tools incorporating innovative 3-D animation as relevant digital resources to enhance the interest and motivation of students towards further science investigations.

Literature Review on Framework of Practice

This section discusses various frameworks of practice, models and strategies that could be employed to plan lesson activities incorporating ICT.

Lesson study approach for Continuing Professional Development (CPD)

Lesson Study can be seen as a form of Action Research as it involves the cycle of 'Study, Plan, Do research lesson and Reflect' analogous to the 'Plan-Act-Observe-Reflect' cycle as suggested by Kemmis and McTaggart (1988). It is widely used in Japan as the main form of teacher Continuing Professional Development (CPD). It was initiated as a model for teacher development in mathematics education and was practised by Japanese teachers for more than 40 years either in government in-service training, special interest group, teachers' club or more commonly as a school-based in-service training called 'konaikenshu' (Isoda, 2008; Lim, 2008). Later the approach was adapted in other topics such as science and it was also widely practised in countries like the United States of America and Australia. It provides teachers with the opportunity to share insights and discuss issues in mathematics and science education particularly in the area of lesson planning and implementation. It could also serve as a tool for building collaborative professional communities, improving instruction, and increasing student achievement.

More specifically, Lesson study (Yoshida & Fernandez, 2002) or sometimes being referred to as Research lesson (Lewis & Tsuchida, 1998) allows teachers to work collaboratively in order to:

- devise long-term goals for student learning;
- plan, conduct and observe a lesson together;
- carefully observe student learning, engagement, and behavior during the lesson; and
- discuss and revise the lesson and the approach to instruction based on these observations.

The research lesson is taught in a regular classroom, and the researcher observe as the lesson unfolds in the actual teaching and learning context. Discussion following the lesson is developed around the data collected from student learning during the observation. Through the process, teachers are given opportunities to reflect on their teaching and student learning.

The findings from United States revealed that Lesson Study improved teachers' instructional practices and enhanced the professional growth of mathematics teachers. These teachers became more confident and reflective and develop collaborative relationships among practitioners. This approach is also an essential contributing factor for high achievement in Mathematics for Japanese students in the 'Trends in International Mathematics and Science Study' (TIMSS) (Lim, 2008). Research conducted in the SEAMEO region also showed that Lesson Study approach was able to assist teachers to move away from traditional teacher-centred practices towards methods that engage their students actively in the learning process as in the "Active Mathematics in Primary Schools" (AMIC) Project involving Brunei upper-primary teachers in a large-scale professional development project (White, 2005).

Multimedia as resource materials for technology-based learning

Multimedia is one of the most effective ICT applications in enhancing science learning. Pictures, graphics, video sequences, sound and text can be incorporated into packages to provide or present information which can be stored and accessed on a variety of media, e.g. CD-ROM, laser disc, video disc, and the Internet (multimedia on the web). An effective educational multimedia consists of the following features: (1) Objective and content (relevant, short and simple); (2) Presentation and effectiveness (gaining attention, cost effective, hyperlinks, and so forth); (3) Interactivity and navigation (interactive activity/quiz, navigational tools, and so on); (4) Feedback as well as drill and practice (elaborative feedbacks, authentic questions, distractors, and so forth) (McFarlane, 1994).

There are many ways to describe the use of animations for teaching and learning. Animations can be used by the teacher for interactive teaching to facilitate students' learning, either individual learning with student working alone, group learning with students working with their peers, or the students working with peers facilitated by teacher in a classroom with one computer or many computers. Animations can be designed for students' learning and understanding, for example, to provide an overview of the content and context in science learning. In addition, animations can be used to sustain learners' motivation, as it is made more interesting to view through the pedagogy and realism with aesthetical appeal. Most importantly animations can be used to provide the proper perspective or realism for events that are seldom available to be experienced directly in the real world (Robert Peter, et al., 2009). Although the content of two recent literature suggests that progress is being made (Mayer, 2005; Lowe & Schnotz, 2008) on our understanding of animations for teaching and learning, many of the studies stated are on university students done under laboratory conditions. These studies also focus specifically on comparing the effects of addition and removal of specific features of the multimedia animation to improve design. Rather than artificially forcing students to learn only from multimedia animations, the direction taken by this research is to focus more on how students and teachers in real school classroom use EUREKA with support from peers, teachers as facilitators and texts like textbooks as suggested by Kozma and Russel (2005).

All the technology-based learning devices have been classified under the recently defined term, Information and Communication Technology (ICT), which includes systems that enable the collection, structuring, manipulation, retrieval and communication of information in various forms, normally via the use of computer and other technological devices (McFarlane, 1994).

In order to achieve the objectives of science learning using ICT, some practical procedures should be adopted as follows:

- Select the educational multimedia with good content and characteristics, relevant to the curriculum topics to enhance effective learning; and

- Integrate the use of multimedia with innovative teaching strategies, such as cooperative learning, constructivist approaches (McFarlane, 1994).

There are various definitions and examples for technology-based approaches in enhancing teaching-learning activities. The commonly used technology in education includes word processing, PowerPoint presentation, ICT graphics tools, multimedia and Internet, simulation, spreadsheet and data logging through computer or calculator. Basically, technology-based learning via computer has been defined as computer assisted/aided learning (CAL), computer assisted instruction (CAI) or computer based training (CBT). Simulation and modelling are important forms of CAL/CBT or educational multimedia programmes for learning. Nowadays, the term multimedia is often used instead of CAL, CAI or CBT because all educational software look like regular multimedia products (Min, 1998) whereas technology-based learning via calculator has been defined as Calculator-Based Laboratory (CBL) and Calculator-Based Ranger (CBR). The Calculator-Based Laboratory (CBL) is a portable, hand-held, battery-operated data collection device for collecting 'real-world' data. Data collected with a CBL can be retrieved and analyzed by a graphing calculator. With the CBL and appropriate sensors or probes, measurements can be taken for example, on motion, temperature, light, sound, pH and force (TI, 2000). The Calculator-Based Ranger (CBR) lets students explore the mathematical and scientific relationships between distance, velocity, acceleration and time using data collected from activities they perform. Students can explore mathematics and science knowledge as well as skills such as motion, graphing, functions, calculus, statistics and data analysis. With CBR and a graphing calculator, students can collect, view and analyze motion data without tedious measurements and manual plotting (TI, 1997).

Constructivist teaching via Children's Learning in Science (CLIS) model

The recent research into students' conceptions has many implications for both teaching approaches and curriculum design. Constructivist views of teaching approaches stress the importance of shared meanings between teachers and students during the teaching and learning process. An example is the Children's Learning in Science (CLIS) model that is developed by the influential CLIS group (Driver & Bell, 1986) based in the UK which is similar to the generative learning model. The following points are emphasized in this model:

- Learning outcomes depend not only on the learning environment but also on the knowledge of the learner. The knowledge of the learner can assist or can interfere with learning.

- Learning involves the construction of meaning. Meanings constructed by students from what they see or hear may be different to those intended. Construction of meaning is to a larger extent influenced by their prior knowledge which can be identified via various approaches such as the use of concept maps or other metacognitive or ‘learning to learn’ graphic tools suggested by Novak and Gowin (1984).

- The construction of meaning is a continuous and active process. Children struggle to construct meanings about their world ever since they were born, and this process continues both in and out of school throughout their lives.
- Meanings that are constructed are evaluated by the learner; and may be accepted totally, accepted in a limited context only, or rejected.
- Learners have the final responsibility for their own learning. They should be encouraged to undertake self-directed or independent learning. Thus, a teacher can never learn for a student, and teaching is never more than the offering of opportunities for learning.
- There are identifiable patterns in the types of understandings students construct, due to shared experiences with the world, and due to cultural influences through language. Thus, the conceptions uncovered in the literature tend to be common across a wide range of culture.

In the CLIS model, the steps in the teaching and learning activities are divided into a consecutive 5 phase lesson. The following is the summary of processes to be incorporated in this research lesson.

Phase I: Orientation

During this phase, the teacher will provide an environment which is conducive to the prepared teaching and learning activities so as to motivate or attract the students’ attention. The activities that could be carried out include demonstrating a simple experiment, some photographs or pictures, a short paragraph in an article, a brief simulation integrating the use of ICT such as CD-ROM, slide show or 3-D animation video clips.

Phase II: Elicitation or generation of ideas

Constructivist views emphasize the need to continually monitor students’ views, to bring them into the open for discussion and evaluation in the light of evidence. The details of the teaching strategies will be influenced by the views of the status of these intuitive conceptions. During this phase, the teacher will encourage the students to exchange ideas in order to stimulate them towards re-examining their previous ideas. This could be done by having brainstorming sessions, roundtables, group discussions, concept mapping, or conducting simple experiments and reporting on what the students do in their respective groups.

Phase III: Restructuring of ideas

During this phase, teacher will take the opportunity to prepare various teaching-learning activities that are suitable for helping the students to clarify and exchange ideas. Teacher could illustrate or provide opportunities for students to visualize the many complicated scientific concepts, principles or theories that could hardly be explained by plain text or ‘chalk and talk’ using 3-D animation multimedia software. Students could also be exposed to certain conflict situations, and thus given a chance to challenge, criticize, evaluate or change their original ideas or those of their friends. It is believed that through this method students will construct new ideas which are more acceptable and can be understood easily.

Phase IV: Application of ideas

In this phase, students will be given the opportunity to use their new ideas to solve problems and explain the phenomenon related to these ideas, possibly in different contexts or problem scenarios. Various investigative and elaborative activities, e.g. project-based activities or problem-based learning (PBL) can be created in this phase to provide more in-depth studies on the topics to be researched.

Phase V: Review change in ideas or Reflection

At this stage, students will be required to make a comparison of their original and new ideas and to review or reflect on their learning processes. The activities that could be carried out at this phase include making a summary, writing ideas or opinion, discussing in groups or writing reports, and exchanging ideas via non-digital or digital mode using web-based programme, to name a few.

Sample Lesson and Implementation Procedures

Objectives and processes in research lesson towards developing a CPD model

The authors had undergone the process of planning, implementing, monitoring and evaluating the outcome of the aforementioned training workshops to introduce the use of animation software. The piloted secondary science lesson plan on the Form 4 Physics topic of 'Energy and Heat' is delineated in ***Appendix I*** with the lesson study processes that include 'lesson planning, presentation, and reflection' which were implemented among students in a local school within the periods of September to November 2008. The estimated time frame of the lessons could be two periods (of 40 minutes each) and the third session could be carried out as two lessons (30-40 minutes each) or as co-curriculum/enrichment activities.

The social objectives of this lesson are the inculcation of values, scientific attitude, interest, motivation, effective communication and cooperative skills. Students should also be able to follow proper guidelines and measures of netetique should they need to surf the Internet for any resources.

The academic objectives to be achieved include the students' abilities to:

1. define and describe the various concepts and examples of 'energy and renewable energy';
2. understand the principles of 'conservation of energy' after viewing 3-D animation software;
3. illustrate the different concepts and principles of 'energy' using metacognitive or ICT graphic tools;
4. explore the numerous concepts related to 'energy and heat' using 3-D animation software;
5. follow instructions to plan, carry out investigation using data logger and science or ICT equipment;
6. collect, organize and interpret data using ICT equipments;

7. surf the Internet and able to communicate or exchange findings with other schools using email or web-based learning facilities;
8. assess and evaluate learning using proper evaluation tools;
9. summarize findings or learning outcome using ICT presentation tools (e.g. MS-PowerPoint).

The series of lesson activities were carried out with the assumption that students have been exposed to the constructivist approaches and metacognitive strategies. They have also acquired the skills in handling and manipulating data using computer, multimedia 3-D animation software, CBL and CBR in the previous lessons. Hence the detailed information on the constructivist, metacognitive strategies as well as computer literacy need not be elaborated further by the teacher during class activities. The 'planning, implementation and review' of the Physics lesson 'Energy and Heat' is elaborated as follows.

(1) Lesson Planning

Setting lesson objectives. During the first step of lesson planning, the lesson objectives and how the lesson should be presented were drafted. The authors decided on the lesson objectives, including what kind of knowledge, skills, attitudes or values that the students need to acquire from the class. A lesson plan was designed to achieve the lesson objectives in line with the content of the entire unit being taught. Various students' responses were also predicted to make the lesson flexible.

Use of multimedia and ICT tools as resource materials. Next the teacher selects instructional materials and teaching aids that are appropriate for the lesson objectives and the students' knowledge and experience. These included the use of multimedia 3-D animation software, concept map labels, Inspiration programme software, Calculator-Based Laboratory (CBL), Calculator-Based Ranger (CBR) and/or computer interface data logger (using probe and sensors), experimental set for "stored and kinetic energy" work card no. 3 and 10 (Windale, 2000). The teacher may create his/her own instructional materials, such as investigation guide, that are tailor-made to motivate the students' desire to learn.

CLIS model as specific steps for the lesson. Finally the teacher develops specific steps, in this case the CLIS model as mentioned above (refer to ***Appendix I*** for the summary of lesson sequence or the sequence of events of instruction) for teaching the lesson. The teacher may consider how the students may act and think at each step of the lesson. At the same time, the teacher also thinks about what kind of questions to ask and how the blackboard could be used. The head of science department for this school (who had experience using the EUREKA software) was also invited to review the lesson. She may give input on the teaching plan or a preliminary review meeting with other teachers may be held to seek advice on areas to be improved.

(2) Lesson Presentation

Presentation. After going through the aforementioned preparatory steps, the lesson is presented and observed by a number of teachers. The lesson is taught according to the lesson plan. However, since the students' responses are unpredictable, the teacher has to be ready for any ad hoc questions. The teacher has to be open to the students' ideas (e.g. as can be viewed from the concept maps developed by them). These ideas could be incorporated into the lesson by adapting the lesson objectives. It is aimed to make the classroom an active learning environment.

Observation. Observers, inclusive of the head of science department and subject teachers, on the other hand, watch or observe the classroom activities from the viewpoint of the teacher (i.e. how to conduct the class) as well as the students (i.e. how they learn). They prepared for a lesson reflection to be conducted later. They should focus not only on how the teacher delivers the lesson but also on how the students were learning and where they may have made mistakes.

Figure 1. Input on EUREKA during workshop by R2 and preparation before the tryout of research lesson by R1, R2 and R3.

The following is a brief account of the preparations made prior to the conduct of the research lesson and the observation on the implementation of lesson plan (***Appendix 1***, ***Figure 1*** and ***Figure 2***):

- The workshops to provide input on the use of EUREKA animation software was conducted by the second author (henceforth being referred as R2) at the end of August and early September 2008 (Robert Peter, et al., 2009).

- Between August and mid-September, the lesson plan was drafted by the first author (henceforth being referred to as R1). Discussions were made among the authors for improvement and revision was made based on the comments by subject teachers who would be involved as observers in the lesson study.

- There were two main teaching sessions conducted by the third author (henceforth being referred to as R3) assisted by the first author (or R1). The first session is the ‘Orientation and Elicitation of ideas’ phases. Students were given the concept map labels to work on in their respective groups after the input session. They were also instructed to compile their learning output in the portfolio to be evaluated by teacher later.

- The second session covered the ‘Restructuring of ideas’ and the input to the ‘Application of ideas’. The latter would be carried out later by the project teams as self-directed learning activities (within the months of October and early November) that include the incorporation of reference resources from Multimedia (e.g. 3-D animation software) and problem-based learning activities.

- The observers or members in the lesson study group were invited to provide input on the lesson plan as well as observing the two main teaching sessions covering the four phases of the CLIS model. They were also involved in facilitating the activities by the project teams later and provided input or comments in the review session at the end of this lesson study cycle.

Figure 2. Demonstration on the animation software by R1; Input of lesson sequence by R3 and students' interactive activities with EUREKA.

(3) Lesson Reflection

Reflecting lesson. This is the most important step in the cycle of research lesson using lesson study approach. The teacher who presented the lesson (i.e. the third author) provided an overview of the lesson and listen to the comments from other members of the team who had observed the lesson. The objectives of the lesson were described and comments were given on the lesson, followed by a 'question and answer' session.

Recommendations for improvement. After the presentation by the third author or R3, then the members of the team (comprised the first, second authors with other school teacher who had observed the lesson) made recommendations for improvement. Concrete alternatives were suggested by the members of the team on how the lesson can be improved, for example what would or should have been done differently to make the lesson better. The facilitator of the group (i.e. R1) had tried to ensure that the discussions stay on track. These discussions not only nurture the professional development of the teacher presenting the lesson (i.e. R3), but allows all the participants to learn to observe a lesson. They also pay attention to how the students think and express their ideas and how the teachers should best interact with them. What they have learned through this step was applied later in the subsequent lesson study in other classes that may be taught by another teacher who is also one of the members of the first cycle of research lesson.

Figure 3. Summary of lesson sequence and collaborative lesson reflection.

The following is a brief account of the comments and feedback given in the lesson study group (consisted of 4 members i.e. R1, R2, R3 and another school teacher R4 who observed the lesson) for the improvement of the lesson incorporating 3-D animation software (refer also ***Figure 3***):

- R1 suggested to make the lesson more focused concentrating on how to use EUREKA to teach science concepts that are difficult to be explained using text-mode or transmission approach.

- R3 suggested to highlight the important features of 3-D animation software to facilitate science learning, not merely as an extension of science text-book.

- R4 suggested to explore the possibility of incorporating part of the content of the 3-D animation software inside presentation of a unit of science to be introduced with possible interactive activities.

- R3 suggested to summarize the content of the video clip into simple, easy to understand language explaining science concept so that students could understand better the narration of the 3-D animation software.

- R2 suggested to make room for more student-centred learning activities using the 3-D multimedia software. For example, (1) How students can be involved in science learning. (2) How self-access or self-directed learning can be made possible without teacher's presence in classroom.

- R1 suggested to explore the content of the software that could possible serve as useful resource or stimulate students' creative thinking for further investigative activities such as problem-based learning.

Conclusion

ICT has been identified as one of the effective tools in recent years to extend the knowledge of learners through extensive research and interactive activities over the Internet. Nonetheless, students should also be allowed to gain confidence in trying out new ideas in a variety of contexts using diverse teaching-learning strategies integrating ICT. Students should also keep abreast with the latest technology and be aware of the various advances which could enhance their thinking skills, not excluding also being provided with opportunities for them to identify changes in their ideas. A supportive learning environment with pedagogically rich teaching strategies integrating ICT is the most appealing contribution for educators and learners in this technologically advanced era. An important aspect of learning is to provide experiences which relate to students' prior knowledge and also give the students opportunities to extend their knowledge and make links between phenomena, with constant provision of experiences that challenge their ideas.

In this research lesson via lesson study approach, the use of ICT animation software was incorporated in the constructivist teaching via Children's Learning in Science (CLIS) model. Lesson study approach could enhance the quality of teaching and learning experience that teachers could provide to their students. Apart from the study and design of lesson plan to ensure implementation of quality teaching, the authors who are part of the team members in the lesson study group had gained enriched knowledge and skills from tryout and the lesson study processes. It is hoped that the experiences acquired from this research lesson would be of significance to:

- the teachers for future adaptation of lessons in their science classrooms.
- the trainers for future planning of sample science lessons during in-service training courses.

Moreover the constructive feedback during the reflection from team members of the lesson study group served as rich-data source for authentic evaluation, thus the authors were able to reflect on their own practice and make necessary changes for future practices.

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Appendix I

An overview of the lesson sequence for teaching the Physics topic on "Energy and Heat"

Phases of event *(time)*	**Activities/Questions posed by**		Strategies/ Approaches and Thinking Skills	**Teaching aids /Materials**
	Teacher	**Students**		
Orientation (20 minutes)	-Teacher to demonstrate the procedures to use EUREKA 3-D animation software. Then a video clip on topic related to the lesson was shown to provoke students' interest in learning.	-Students to take note on the procedures to use. Working in pairs, students take turns to have hands-on activities to use multimedia viewing the 3-D animation software.	*Multimedia/ICT tool *Cooperative learning (Think-pair-share) *Scientific/ICT skills (Observing, Communicating, Computer skill)	- Computer with access to EUREKA multimedia (3-D animation software)
Elicitation of Ideas (30 minutes)	- Teacher to ask diverging questions about what happens when ice is heated or water is boiling	- Students to discuss in groups and a representative will deliver the group's explanation.	* Questioning * Task-based learning – group discussion * Brainstorming	-Drawing paper and colored pens
(optional)	-Teacher to explain the pro-cedures of concept mapping and instruct the students to make a comprehensive concept map with suitable linking words using the concept labels given. -Teacher to demonstrate the methods of using ICT graphic tools to draw concept maps, i.e. by MS-Word or Inspiration programme software.	-Students in groups of 4-5 to brainstorm their ideas and understanding on the various concepts and principles of 'Energy and conservation' by writing the suitable linking words to interconnect the con-cept labels and show the definitions or interrela-tionships among concepts. -Students to draw concept maps using ICT software.	* Brainstorming *Team study *Metacognitive strategy (Concept mapping) *Scientific skills - Observing -Communicating -Classifying *ICT skills (Manipulating ICT equipments, Use of ICT graphic tools)	-Concept map labels -Mahjong paper or A4 paper to be compiled in portfolio -ICT graphic tools (MS-Word or Inspiration programme software)
Restructu-ring of ideas Step 1 (5 minutes)	- Teacher to assess the presentation of the students. Teacher delves further by questioning to get students to accept or refute their own	- Students try to explain again after being asked further about the explanation that they have given to get a convincing answer.	* Focused questioning *Repeating student's explanation to confirm answers.	- Drawing pens and drawing paper

Phases of event *(time)*	**Activities/Questions posed by**		Strategies/ Approaches and Thinking Skills	**Teaching aids /Materials**
	Teacher	**Students**		
	explanation			
Step 1 (optional) (5 minutes)	- Teacher to assess the concept maps developed by the students together and identify any misconceptions.	-Students to carry out peer evaluation monitored by teacher, will modify their misconceptions, if any.	* Peer evaluation * Alternative assessment * Scientific (Observing, Communicating) skills	- Concept maps labels printed from computer
Step 2 (10 minutes)	- Teacher to show video clips on the following topics that were identified to be difficult for students to understand or visualize: (1) Understanding specific heat capacity (s.h.c.) (2) Understanding latent heat	-Students to pay special attention with note-taking on the following features illustrated in the 3-D animation software: (1) concept of s.h.c. (2) latent heat of fusion, bonding of molecules	* Scientific (Observing, Communicating) skills * ICT skills (use of technological tool) * Team study * Higher Order Thinking Skills (HOTS) * Peer evaluation	- Computer with access to PowerPoint presentation and 3-D animation software
Activity 1 (optional) (30 minutes)	-Teacher to provide materials such as solar PV cells, circuits and other materials, e.g. heat or temperature probe, wind vane.	-Students in project teams to carry out experiments related to RE, including solar, heat, wind, water and/or mechanical energy.	*Group investigation *Scientific/ICT skills (experiment, ICT tools) *Higher Order Thinking Skills (HOTS)	- Experimental sets for RE -ICT tools (eg.CBL/CBR and GC)
(optional)	- Teacher to divide the class into teams with each team consisting of three sub-groups (e.g. Sub-group 1 to make hypothesis before carrying out investigation.)	-Students to be divided in project teams and carry out investigation.	*Scientific skills (all experimenting skills) *Data logging *Higher Order Thinking Skills (HOTS) (creative /critical thinking)	-Experiment worksheets -CBL data logger, Graphic Calculator
	- Teacher to demonstrate the use of CBL (temperature probe) to collect data of the changing temperature of	-Students working in project teams to make hypothesis prior to the investigation with regard to the effect of the changing position	*Group investigation *Scientific skills (Observing, Hypothesizing, Measuring,	- Experimental set “Global Solar” (map,

Phases of event *(time)*	Activities/Questions posed by		Strategies/ Approaches and Thinking Skills	Teaching aids /Materials
	Teacher	**Students**		
	water, Graphic Calculator (GC) and facilitate students to conduct science investigation.	of sun towards the length of shadow of the object...	Communicating, Collecting data, Interpreting data, Drawing graphs, etc.)	compass, meter ruler, plastic bottle, measuring jug, thermo-meter, graph paper, etc.)
(optional)	- Sub-group 2 will be instructed to interpret data and compare their findings with the findings collected from CBL and GC. -Teacher to demonstrate the use of Internet to enter data and exchange information using web-based learning activities via SAW website.	- Students to carry out investigation in three sub-groups (Measuring the Sun's position, Solar hot water and Measuring the Sun's energy). -They will compare their findings with the findings collected from CBL, later carry out web-based learning to exchange information with other countries.	*Group investigation *Scientific/ICT skills (Experimenting, Manipulating science and ICT equipments, Computer literacy, Comparing, Data logging, Emailing)	- Experimental set "Global Solar Unit" - CBL, GC - Experiment Worksheets - On-line exchange form
Application of ideas Activity 1 (15 minutes)	- Teacher to provide problem scenarios on "RE and Heat" - Teacher to give input and facilitate students' PBL activities.	- Students in project teams to make hypothesis in various scenarios and identify variables for investigative activities	*Team study *Scientific/ICT skills *PBL activities *Investigative projects	-PBL scenario -Guide and worksheet for PBL activities
	-Teacher to show various scenarios of the application of scientific ideas in daily life via 3-D animation. The following were illustrated: (1) Energy and chemical changes: The voltaic cell (2) Generation of electricity: Water energy	- Students were to explore ideas on the application of science in daily life. Students were to prepare investigative project, e.g. to illustrate the concept of how water energy was harnessed to generate electricity.	*ICT/Scientific skills (Harnessing digital resources, observation) * Techno-challenge * Higher Order Thinking Skills (creativity, problem-solving)	-Multimedia (3-D animation software)
(optional)	- Teacher to give example of 'hypothesizing'. Experiment that	- Students were guided to make hypothesis in terms of e.g. "The longer the	*Scientific skills (Observe, Hypothesis, Design	-Instruction sheet with Experimenta

Phases of event *(time)*	**Activities/Questions posed by**		Strategies/ Approaches and Thinking Skills	**Teaching aids /Materials**
	Teacher	**Students**		
	could be carried out is "Making a band roller" with instruction sheet given.	length of the long rod, the further/nearer it will go". - Students were to test their hypothesis by investigation	experiment, Investigating, Identify and control variables, Interpreting data, Drawing graph, etc.)	1 set (elastic band, rod) -Energy kit work card 10
Activity 2 (10 minutes)	-Teacher to facilitate PBL project teams, demonstrate web-based exchange.	- Students in project teams were to carry out PBL activities, exchange findings, surf Internet.	*PBL activities *Scientific/ICT skills (Communicating, Web-based learning)	-Internet
Review Change of Ideas or Reflection (10 minutes)	-Teacher to discuss and summarize the students' under-standing regarding the topic. -Teacher to revise with students the MS-Powerpoint software and instruct students to present their summary using MS-Powerpoint incorporating graphics.	-Students to summarize their understanding using various constructivist learning tools, graphic organizers and Clip Art. -They will transfer their learning onto the computer using MS-Powerpoint.	-Communicating -Graphic organizers -Group presentation *Scientific/ICT skills (Communicating Manipulating science and ICT equipments, ICT graphic skills, Computer literacy)	-Computer graphic (Clip Art) -MS-Powerpoint