Fostering Thinking Skills Supported by e-Portals with Case Examples of Blended Mode Problem-based Learning (PBL) Participated by Secondary School Learners

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ABSTRACT

The integration of Information and Communication Technology (ICT) in science learning has been identified as an important component in the transformation process of many educational systems to impart the technology skills that is an essential 21st century skills to serve the new learning paradigm among the Net Generation students. In the advent of digital era, World Wide Web has spawned a wealth of new network-based applications with an overarching vision that supports specific blended mode learning programmes incorporating interactive e-platforms and m-learning. Student-centred learning opportunities were widened with more interactive activities that could engage their interest for science learning in the ever expanding knowledge-based societies. This article analyses the roles of e-portals incorporating Open Educational Resources (OERs) that foster thinking skills of learners through 'Problem-based Learning' (PBL) programmes. Cases are extracted from a bigger scale of longitudinal study that examined students' participation in the blended mode PBL anchored on social constructivist and socio-cultural framework. Blended learning activities were implemented leveraging on the effective use of OER to enhance learners' investigative skills with transformation of values-based classroom practices beyond formal teaching. PBL scenario (six contextual problems) adapted from secondary science entitled 'Water and Solution' was presented to project teams from two case study schools. Problem case 4 using 'within-case dynamic matrix' was further reported with exemplars elaborated. Students were administered with 'Fluid Intelligence Test'(FIT) encompassing evaluation of creative, critical/logical thinking and reasoning skills prior to PBL through scaffolded instruction (SI)(PBL-SI) with evaluation guided by POSITIVE rubric (accessible at http://forum.sp3aceman.net). Four aspects of PO**SIT**IV**E** rubric guide, '**S**kills' enhancement (scientific/ICT), '**I**nformation', '**T**raining/transfer of Higher Order Thinking' (HOT) and '**E**valuation/exchange/enrichment/ exposure' are illustrated with evidence of students' enhanced HOT. Innovative learning designs and on-line assessment with evidences of exemplary students' creative potentials involved in investigation using OER were identified which include interviews findings from two students who created web-portals using OER effectively. 'More/moderately successful students' were involved actively in mini science fair, congress/competitions and e-forum (http://forum.maays.net). Other pedagogical issues concerning of the importance of PBL and blended learning that promote thinking skills in line with research evidence as reported in TIMSS and PISA studies are also deliberated.

Keywords: Fostering thinking skills, Problem-based Learning (PBL), Open Educational Resource (OER), within-case and exemplary case analysis, blended mode of learning, transforming instructional practices with flexible assessment

INTRODUCTION

The study on human's thinking capacity has always been a prime concern of many educational psychologists and researchers who are interested to stimulate Higher Order Thinking (HOT) and promote innovative performance among learners with transformation of identity. In the advent of digital era, interactive e-portals as major *trends* of technology-enhanced learning were shown to be effective to widen student-centred learning opportunities in the ever expanding knowledge-based society. The issue lies on how educators could harness the effective use of Open Educational Resources (OER) and new paradigms of teaching approaches to foster creativity among young learners and digital natives. Hence the *problems* of practice through e-platforms have been important research focus areas for educational researchers. Many blended mode of learning initiatives (i.e. both digital/on-line and non-digital/off-line) provide useful tools for effective and ever-expanding global learning platforms to promote web-based collaborative projects involving contextual problem-solving skills as reflected in project-based activities (PBA), problem-based learning (PBL) and participatory inquiry (PI). All these approaches combine investigation, education and purposeful action with knowledge creation and transformation through shared blended learning in contrast to the transmission approach. Participants in these aforementioned activities are capable of growth, change and creation (Briton, Collett & Cooney, 2010).

BACKGROUND

This paper illustrates on two e-portals that aim at promoting HOT especially creativity through blended learning activities leveraging on available OER, i.e. '**S**cience **P**roject/problem/programme-based **A**ctivities in**C**orporating **E**xperiment **MAN**agement' (SP3ACEMAN) and '**M**agnificent **A**dvancement of **Y**oung **S**cientists' (MAAYS). Case studies are extracted from part of a bigger scale of longitudinal study that examined secondary students' participation in a specially designed PBL programme through scaffolded instruction (henceforth abbreviated as PBL-SI) activities via ICT integration incorporating student-centred learning approaches using social constructivist and socio-cultural theories as framework of reference.

OBJECTIVES

The following are the objectives of the research activities reported here:

- To illustrate the blended learning activities that were implemented in this PBL programme facilitated through SP3ACEMAN and MAAYS e-portals with effective use of OER.
- To report on within-case analyses of the enhanced HOT as measured in the fluid intelligence of students who had participated in PBL programme with exemplars elaborated.

LITERATURE REVIEW AND FRAMEWORK OF STUDY

The nature and key theoretical perspectives of creativity, definition/research on OER will be reviewed with identification of framework of study that guides direction of research activities.

The Essential Elements of Creativity as an Aspect of Fluid Intelligence or Higher Order Thinking

Human's thinking is illustrated in numerous ways. The term Higher Order Thinking (HOT) is often defined operationally as the thinking that requires learners to reconstruct the information and ideas so that their meaning and implications can be transformed in a logical manner. This process of transformation occurs during scientific reasoning or when students combine facts and ideas in order to explain, apply, analyze, synthesize, generalize, hypothesize or arrive at some conclusion or interpretation. Students may demonstrate HOT through tangible products or projects as learning output. The intangible (e.g. creative ideas) learning output may involve students' ability to perform various tests with evidences of lateral thinking, metaphorical thinking or use of analogies and metacognition (e.g. monitoring and evaluating own thinking). There is thinking that concerned with description (e.g. verbal fluency) (Bloom, Hasting & Madaus, 1971; de Bono, 1985; Sale, 2008; Sill, 2001; Torrance, 1974). There is thinking based on action such as participation in active learning and problem-solving (PBS) activities in PBL through blended mode of instruction. There is also integrative thinking including synthesis, creative/critical thinking, decision making (Baird, 1990 in Fensham, Gunstone & White, 1994; Phillips, 2007) that influence intelligence, learning, and motivation (Nigam, 2009; Paris & Winograd, 1990; Scruggs, Mastropieri, Monson & Jorgenson, 1985).

The concepts of creativity overlap with those of intelligence and thinking (Linn, 1989). It is believed that creativity could also be fostered to a certain extent using appropriate instructional pedagogies. However, research showed that creativity is a complex construct that can be expressed in many ways (Treffinger, Young, Selby, & Shepardson, 2002). Hence it poses great difficulties to identify creative strengths among students in a fair and meaningful way especially for those from diverse socio-cultural background and achievement. Creativity tests were mostly designed based on review of theories and research findings by prominent psychologists [e.g. Amabile (1983), Gardner (1993), Guilford (1987), Torrance (1974)] who revealed that students may demonstrate any of the four sets of characteristics in varied ways. There are four personal creative characteristics suggested by Treffinger *et al*. (2002), i.e. people who are able to 'generate many, varied and unusual possibilities' are defined as creative thinkers. The characteristics in 'digging deeper into ideas' include such as analyzing, synthesizing, evaluating, seeing relationships. The characteristics in 'openness/courage to explore ideas' including sensitivity, curiosity, humour, imagination, and risk-taking in trying new ideas, e.g. science learning/investigation supported by non-digital/digital resources. The characteristic of 'listening to one's inner voice' is often associated with self-awareness of creativeness, perseverance and motivation. Researchers should also bear in mind that it is vital to use varied methods and multiple data sources to evaluate creativity (de Bono, 1985; Treffinger *et al*., 2002).

Manipulating information and ideas through numerous processes of HOT allows students to discover new meaning for their learning and solving difficult problems. When students are engaged in the construction of knowledge, e.g. in PBL integrating ICT harnessing on OER, an element of uncertainty is introduced. Therefore it makes instructional outcomes not always predictable, i.e. the teacher is not certain what will be produced by them. In helping students to become knowledge producers, the teacher's main task is to create activities or environments that allow them the opportunities to engage. It was suggested that there is a need for the researcher to define the specific types of thinking to be assessed before identifying appropriate sources of performance evidence, subsequently producing valid and practical scoring system (Sale, 2008). However, there are also constraints and limitations to be acknowledged for evaluation of certain aspects of HOT. For example, researchers believe that '*creativity can be expressed variedly; no one person possesses or displays all creativity characteristics all the time*' (Treffinger *et al.*, 2002).

Evaluating Problem-based Learning using Open Educational Resource

In this study, the effect of PBL on HOT was evaluated on three main aspects, i.e. to illuminate evidence on change of '*ability, achievement* and *aptitude'* as manifested by the students. An example is the use of free web software (e.g. WordPress and phpBB) [URL: http://wordpress.org/about/] to create websites as platforms for e-learning. OER are digitized materials being offered freely and openly for educators, students and selflearners to use and reuse for teaching, learning and research. OER include different kinds of '*digital assets*'. The '*implementation resources*' include intellectual property licenses that govern open publishing of materials, design-principles, and localization of (e.g. learning) content. They also include materials on best practices such as stories, publication, techniques, methods, processes, incentives, and distribution. The '*learning content*' includes courses, course materials, content modules, learning objects, collections, and journals. 'Tools' include software that supports the creation, delivery, use and improvement of open learning content, searching and organization of content, content and learning management systems, content development tools, and on-line learning communities (e.g. open and distance education via blended mode of learning activities) (Wikipedia, 2011).

According to Carter (2005), psychometric tests can be broadly divided into two main categories, i.e. tests of 'maximum' performance and potential in a number of areas, e.g. ability or aptitude; and tests of 'typical' performance, e.g. personality or interest. '*Ability*' is defined as 'what the student is able to demonstrate at present'. For example, the student's '*ability*' to perform various challenging tasks related to PBL was evaluated using the evaluation rubric adapted from the PBL support tool (Ng, 2009; Ng, 2010) involving metacognition, i.e. HOT that includes active control over the cognitive processes engaged in learning (Phillips, 2007). '*Achievement*' is 'what the students have accomplished in the past' [e.g. that was evaluated using 'Higher Order Thinking Test in Science' (HOTTIS) (Ng, Fong, & Soon, 2009)]. '*Aptitude*' means 'how quickly or easily the student will be able to learn in future' [e.g. that was evaluated using 'Fluid Intelligence Test' (FIT) (Ng, Fong & Soon, 2010) that includes creativity].

In this PBL programme integrating ICT, the aspect of '*aptitude*' was assessed. Numerous tests on Creative/Critical Thinking (CCT) skills were devised to test several constructs identified in creative/critical thinking as examples of HOT. These include two kinds of ability, i.e. 'fluid-analytic and crystallized intelligence' (Cattell, 1963 in Grieve, 2008). 'Crystallized ability' [e.g. 'Crystallized Intelligence Test' (CIT) that is another aspect being assessed but not elaborated in this article] referred to those areas influenced by experience and training, i.e. students' acquired procedural/conceptual knowledge and skills that are strongly dependent upon exposure to culture. It is the knowledge gained through experience that reflects overlearned behaviors and the products of 'fluid intelligence' (Detterman & Sternberg, 1982; Richard & Zimbardo, 2002). 'Fluid intelligence/ability' (as reflected in FIT, i.e. a paper-and-pencil test that require culture-free mental efficiency) referred to the aspects of intelligence or potential that involves the ability to see complex relationships and solve new problems creatively. It is the successful adaptation in situations whereby previously learned skills are of no extra advantages. According to Haladyna (1999), 'fluid intelligence' could also be evaluated through some common 'fluid abilities' like reading, writing (e.g. e-forum posts), speaking and listening.

The key principles in 'constructivism' (Vygotsky, 1978) that 'knowledge is embedded in the authentic tasks in realistic context (as emphasised in PBL) in which it is used and learning is an active process of constructing knowledge with learners engaged in using tools' are supported by various framework. For example, 'situational approach' is a commonly used pedagogy incorporating social constructivist teaching with emphasis on problem-solving in everyday life. This type of learning is also elaborated as social mediation with participatory knowledge construction whereby interaction among group members (e.g. peer group) serves as the socially shared vehicles of thought with possible support/coach from facilitator (e.g. teacher) who helps an individual to learn. Social mediation could be elaborated by cultural scaffolding [in which the emphasis is on use of non-digital (e.g. books) or digital resources including ICT tools in mediating learning] and with the social entity as a learning system that may bring about changes in its underlying values and norms (McConnell, 2000). Successful learning enriches the experience universe and stimulates further inquiry learning. The output or product of problem-solving activities and PBL integrating ICT (e.g. use of graphic tools and e-portals using OER) in the form of projects allow students to experiment, make decisions, form and re-form hypothesis, test and examine ideas, seek solutions, and most importantly, learn more about themselves and their world (Asimov, 1990). By the end of the twentieth century, the development of 'core/key' skills as explained from constructivist theories, such as problem-solving and decision-making, was found to be embedded in primary and secondary school curricula (VWSCRE, 2000). For example, a thinking skills structured programme namely 'Cognitive Acceleration through Science Education' (CASE) was introduced in UK targeting students aged 11+ to 13+. It is an intervention strategy combining curriculum tasks and pedagogy within the context of science emphasizing two main tasks in HOT. Firstly, students should be able to identify things that matter ('variables'), connections ('relationship', a vital trait of creativity) and types of relationships. Secondly, they should also be able to group things ('classify'), describe, differentiate, explain, predict/hypothesize, compare, infer and summarize (VWSCRE, 2000). Cutler (2004) also stressed the importance to teach knowledge and understanding of how science works through developing key skills, e.g. communication, cooperating, reasoning, enquiry and creative thinking. Thus fostering creativity is a vital aspect to be considered in problem-based science learning.

RESEARCH METHODOLOGY AND DATA COLLECTION

Blended learning activities were implemented in this PBL programme harnessing on effective use of OER to enhance learners' investigative skills and creativity. This section elaborates on research activities aiming at fostering creativity beyond formal teaching.

Developing Research Instrument to Evaluate Creativity

'Fluid Intelligence Test' (FIT) was constructed as an aptitude test to evaluate HOT skills of Form 2 students (ages about 13 or 14) before (pre-) and after (post-) PBL in 2008. FIT was adapted from some validated research instruments, i.e. Torrance's thinking test (1974), 'creative product evaluation' by Gardner (1993), 'creative logic' by Carter (2005) and Eberle (1991), also 'Finding relationship' by Roadrangka, Yeany and Padilla (1982). Table 1 summarizes the content of FIT that evaluate three areas of HOT, i.e. creative and critical thinking (CCT), logical thinking and reasoning (LTR). The specific areas being evaluated are also outlined in the table with indication of 'question number and percentage of marks allocated' in the respective sections (http://forum.sp3aceman.net/search.php?st=0&sk=t&sd=d&sr=posts&author_id=54&start=20). The questions include areas such as 'diagram completion illustrating various creative traits' (e.g. items that evaluate the aptitude of 'originality, flexibility'); 'subjective questions requiring open-ended answers', 'fill in the blanks with identification of correct variables or things that matter with indication of types of relationships' (fluency/flexibility); and 'analysis of picture or figure logically with reasoning or explanation of rationale of choice'.

Table 1 Content outline for Fluid Intelligence Test (FIT) to evaluate Higher Order Thinking (HOT)

Main HOT areas	Sub-theme or specific areas to evaluate thinking skills
Creative thinking **(Questions 1 to 4, 10 items, 40%)**	Originality: Students' ability to produce original, unique or creative ideas.
	Flexibility: Students' ability to solve problems flexibly/creatively with many ways of Problem-solving (PBS).
	Fluency with elaboration: Students' ability to give many elaborative/illustrative examples.
Critical thinking **(Questions 1 to 5, 10 items, 30% in total)**	Identifying variables (things that matter): Students' ability to classify and list variables.
	Analyzing relationship: Students' ability to state hypothesis, identify relationships of the objects based on classification of objects given or from the problem scenario presented.
	Comparing/contrasting: Students' ability to compare similarities and contrast differences.
Logical thinking and reasoning **(30%) (Q1 to 5)**	Students' ability to decide or choose the best solution with logical thinking demonstrating reasoning skills or reasonable explanation for the choice of response in each item.

(Adapted from Torrance, 1974; Gardner, 1993; Carter, 2005; Eberle, 1991; Roadrangka, Yeany & Padilla, 1982)

Two pilot studies were conducted with $N_1 = 40$ (pilot study 1) and $N_2 = 84$ (pilot study 2) selected from secondary student samples of very high, medium and moderately low achievers. Item analysis was implemented to establish reliability and validity of the instrument with the findings reported by Ng, Fong, and Soon (2010) for pilot study 1, as well as by Ng, Soon, Rozhan, and Fong (2011) for both pilot study 1 and 2. Consequently, all the HOT questions that were piloted during pilot study 2 were accepted based on the results of item analysis that showed computed good range of $0.2 \leqslant \rho \leqslant 0.8$ and $D \geqslant 0.25$ (where ρ = Index of difficulty and D = Index of discrimination). The internal reliability for the final version of FIT computed through Kuder Richardson using SPSS statistics software also showed good Alpha value $kr_{21} = 0.9043$.

Designing E-Portals Leveraging on OER to Promote Blended Learning

Two web-based programmes were designed for blended learning activities to facilitate PBL supported via e-portals using the template of 'WordPress' free software powered by phpBB, an OER downloadable from the internet. The e-portals were designed by two secondary students who were involved in pilot studies of PBL programme in 2008 and the content of portals were provided by the founders as advisors/administrators of these portals.

*'**MA**gnificent **A**dvancement for **Y**oung **S**cientists' (MAAYS)*(URL: http://maays.net) is an international education programme founded in 2003 by Vision Academy (M) Sdn. Bhd. An action research study was conducted to document, review and reflect on the efforts made by local, national and international organizations. This study indicated that although there were efforts with thematic focus to develop young scientists through strategic activities such as science camps/fairs/congresses/workshops, there is yet a concerted effort to promote young scientists in a networked environment using information, knowledge and values-based society. This study indicated that although there were efforts with thematic focus to develop young scientists through strategic activities such as science camps/fairs/congresses/workshops, there is yet a concerted effort to promote young scientists in a networked environment using information, knowledge and values-based society. Young scientists who are ICT savvy are expected to be trained as a critical mass to propel the growth of science and technology in digital age. Modus operandi was prepared through concerted efforts to use on-/off-line activities with discussion on pertinent 'Problems, Issues and Opportunities' (PIO) to promote 'Young Scientists' Network' program. An e-platform was finally prepared as venue of collaboration in sourcing human and material resources with the objectives to:

- exchange, share knowledge and promote global understanding on scientific investigation.
- provide opportunity for intellectual venture and as effective medium to promote lifelong scientific/mathematical values, interests, skills, attitudes and motivation among the youth.
- serve all stakeholders as e-platform for participating in the Community of Practice (CoP), encourage further communication, foster camaraderie with collaboration and networking activities that were initiated since the 5th 'Search for SEAMEO Young Scientists' (SSYS) 2006 congress (Kim, 2003).

*‘**S**cience **P**roject/problem/programme-based **A**ctivities in **C**orporating **E**xperiment **MAN**agement’ (SP3ACEMAN)*(URL: http://sp3aceman.net) is a student-centred learning programme founded in 2004 as an off-shoot of the post-graduate research studies aiming at promoting investigative research. It is a sub-portal hyperlinked to ‘**S**outh **E**ast **A**sia **R**egional **C**apacity **E**nhancement *H*ub’ (SEARCH) as illustrated in Figure 1 [URL: http://www.recsam.edu.my/search]. An off-line web-portal was designed initially as platform for sharing of resource materials such as support tools for project-based activities (PBA) (studies between 2003 and 2008) and problem-based learning (PBL) (studies between 2007 to 2011) that were also compiled using CD-ROM being distributed among research samples. This programme was monitored and evaluated using POSITIVE rubric guide (an acronym for ‘**P**lanning, **O**bjective/organization, **S**kills, **I**nformation procurement, **T**raining/transfer of HOT, **I**nvolvement/Incorporating pedagogical-content knowledge (PCK), **V**alues with enhanced motivation and **E**valuation/exchange/enrichment/ever-lasting exposure’). Using ‘WordPress’ OER, an e-portal supported by a closed forum (Figure 2) was also developed to facilitate wider groups of participation towards Education for All (EFA) and fostering creativity with sharing of more OER. This portal is designed for all types of learners with various levels of background knowledge and academic achievement to explore more about investigative research. SP3ACEMAN was introduced with scaffolded instruction (SI) being designed for beginners with support rendered while more challenging activities are also prepared for advanced learners for self-directed/self-paced/self-accessed learning. Some of the research evidences were disseminated by Ng (2009) and Ng (2010) with the resources freely downloadable as OER via URL (e.g. http://forum.sp3aceman.net).

Figure 1 Snapshot of SP^{3}ACEMAN [URL: http://sp3aceman.net]

The index page of SP^{3}ACEMAN [URL: http://sp3aceman.net] as sub-portal to the SEARCH official website [URL: http://www.recsam.edu.my/ search] for on-line learning hub is shown in Figure 1 while Figure 2 shows the closed forum site.

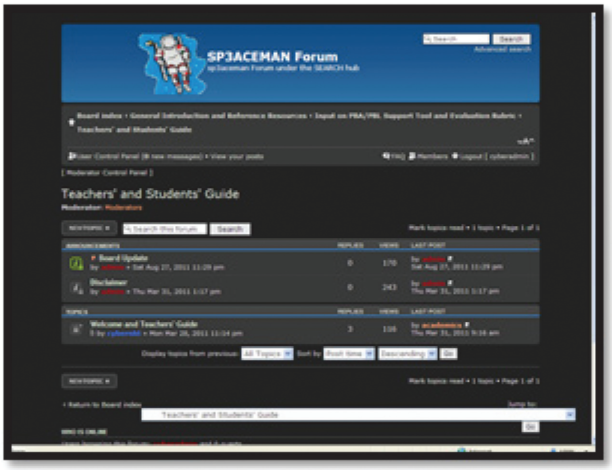

Figure 2 The closed forum site of SP[3]ACEMAN with 'Teachers' and students' guide' provided for scaffolded activities of PBA/PBL [http://forum. sp3aceman.maays.net/viewforum.php?f=28]

Figure 3 Female students' project presentation in mini science fair was posted onto official website of 'Water Watch Penang'

Implementing and Evaluating Learners' Participation in PBL Integrating ICT using OER

Research students were involved in PBL supported by ICT tools that included the two e-platforms as discussed. Problem-based scenario adapted from secondary science topic on 'Water and Solution' with six contextual cases being solved collaboratively in 2008 was presented to project team members from two case studies (male and female) schools. Apart from motivation surveys and other HOT tests, FIT that is culturally independent was administered as pre-/post-tests to evaluate students' HOT for 'fluid intelligence' (including creative/critical/logical thinking). Other main activities included participation in school-based mini science fair by all female research samples (Figure 3); participation in the 7th 'Search for SEAMEO Young Scientists' (SSYS) (2010) (http://maays.net/2010/03/13/ssys-winners-list/#) and i2discovery proposal competition (Figure 4) organized by MAAYS by selected male samples, as well as participation in open forum of MAAYS.net and closed forum of SP3ACEMAN (URL: http://forum.sp3aceman.net).

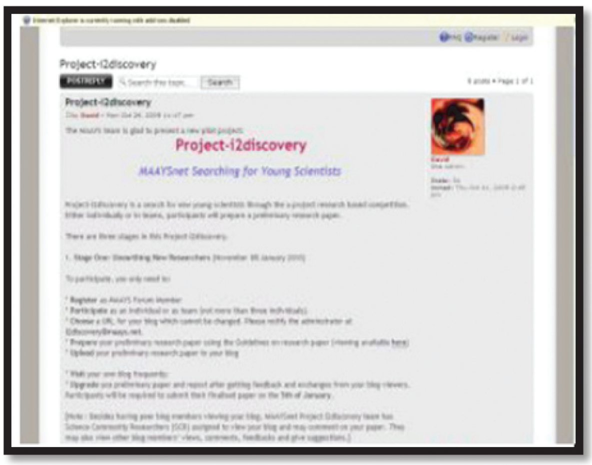

Figure 4 Male students were encouraged to participate in i2discovery proposal competition organized by MAAYS

INTERPRETATION OF FINDINGS WITH ELABORATION ON CASES

Literature revealed that there are five steps to develop 'creativity', i.e. "*Knowledge, Thinking, Incubation, Moment of inspiration and Development*" (Yew, 2001 in Yingprayoon, 2005, p.5). The process of fostering creativity through blended mode of 'PBL via scaffolded instruction' (PBL-SI) was reflected in this 'study on the effects of PBL-SI towards secondary students' HOT and motivation' (Ng, 2012). It was observed that generally the PBL-SI research samples were able to acquire diverse '***knowledge***' utilizing all the five senses through searching the literature from diverse sources of information that were relevant to their project with effective use of OER [i.e. 'Information procurement' (or the first 'I') as required in the POSITIVE rubric]. They were given the 'Training' and encouraged to work in groups to '***think***' deeply and brainstorm ideas using graphic organizers such as concept map and fishbone diagrams that reflect the '**T**ransfer of their HOT'.

There were occasions when students were given opportunities to participate in '**E**nrichment' activities or involve in something unrelated to the problem, i.e.

‘***incubation***’ period, but the resources they gathered were able to ‘***inspire***’ them to prepare projects for mini science fair (by the end of 2008 in female school), research proposals for MAAYS ‘i2discovery’ proposal competition (between December 2009 to January 2010 by a few male students). Selected male students (from project team 4 being illustrated as ‘*exemplary cases*’ later) had participated in ‘***development***’ of project ideas into useful and practical applications guided by MKO with ‘**S**kills’(scientific/ICT) enhancement activities. Subsequently, ‘within-case’ analysis is made to elaborate on each case separately and ‘exemplary case’ being illustrated to ensure that the procedures used are well documented and can be repeated (Eisenhardt, 1989; Miles & Huberman, 1994; Yin, 2003).

Enhancing HOT via PBL Supported by ICT Tools and E-Portals (Within-case Analyses)

‘Within-case’ dynamic matrices were used to summarize PBL-SI of ‘more successful’ selected male and female project team members working on PBL-SI activities for problem case 4 with their enhanced HOT as evidenced in their learning output (accessible from http://forum.sp3aceman.net/viewtopic.php?f=24&t=44). The aspects of students’ HOT (including creative/critical thinking) and metacognitive ability to identify facts/questions, the PBL-SI programme integrating ICT and how these were translated in the problem-solving (PBS) processes were analyzed. Among the strategies used to promote students’ thinking skills include their abilities to identify ‘cause and effect’ with subsequent skills required in the PBL to identify viable hypothesis and three types of variables (i.e. dependent/independent and controlled). It also includes students’ ability to analyze situations with review of related studies for further clarification and the conduct of field work with data collection for dissemination of finding via blended mode activities using e-portals and OER effectively.

The resulting change of each problem case was also analyzed in detail with evidences of students’ enhanced HOT skills after their participation in PBL-SI. These include the analyses on observation rubric and paper-and-pencil test, e.g. ‘Crystalized Intelligence Test’ (CIT) that evaluated their creativity as measured from graphic organizers [e.g. concept map and fishbone diagram (*Image 5*)] using rubric scale {i.e. 4 marks for ‘Excelling’ 75% to 100% of total score), 3 marks as ‘Expressing’ (50% to 74%), 2 marks as ‘Emerging’ (25% to 49%), and 1 mark as ‘Not yet evident’ (0 to 25%)}.

The evaluation rubric (accessible from the ‘Project Schools’ accounts in URL: http://forum.sp3aceman.net/viewtopic.php?f=24&t=44 and http://forum.sp3aceman.net/viewtopic .php?f =52&t=47) was adapted based on the references of creative traits such as originality, flexibility, fluency, elaboration and the four main features of creativity as reviewed from literature. These include the ability to (1) ‘generate many and unusual possibilities’; (2) ‘dig deeper into ideas’; (3) be ‘open and courageous to explore ideas’; and (4) ‘listen to one’s inner voice’. These scores in evaluation rubric were given based on the students’ genuine work, e.g. [4] marks were given if excellent or most accurate answers were produced by the team members who contributed original/creative ideas. Only 1 mark was given to answer of poor quality. They were classified as 'more successful' (and some are illustrated as 'exemplary cases') if they had completed 70% and above (i.e. they participated actively with prompt completion) of the tasks assigned in PBL-SI with score 4 in 70% and above of tasks, also showed improved post-test scores in FIT as reported.

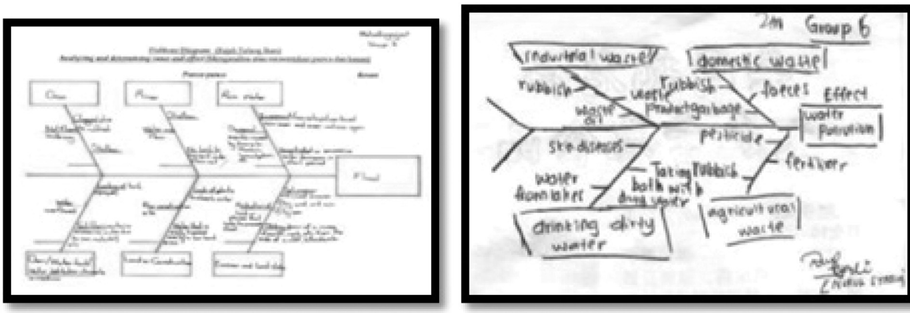

Figure 5 Sample students' graphic organizer learning output 'fishbone diagram'

Students were evaluated on their improved scores in post-FIT as compared with their pre-FIT [that include creative/critical thinking (CCT), logical thinking and reasoning (LTR) skills], metacognitive thinking, conceptual knowledge (HOTTIS) and procedural knowledge/skills [from their scores in 'Science Practical Skills Evaluation' (SPSE) or '*Penilaian Kerja Amali*' (PEKA)]. Other evaluations include their observed motivation level to participate in off-line (all PBL-SI activities or field studies, the mini science fair for female) and on-line activities (e.g. posts on MAAYS e-forum for all; i2discovery proposal competition by MAAYS and research report presented in SSYS for male as can be viewed from e-forums of MAAYS and SP3ACEMAN). Generally all the 'more successful' students as described in 'within-case' analyses for Team 4 members had either shown improvement of FIT scores or with concrete evidences of their participation in all aforementioned activities.

The names of two groups of more/moderately successful PBL-SI students anonymously abbreviated as F(4/1/2)=Female (Team 4/Class 1/Student 2). They are Team 4 female [F(4/1-3/1), RLXY, DV and NCLE] and male [M(4/1/1-4), MSy, MS, MAk, NA]. Within the constraints of limited timeframe, all the PBL-SI female students were able to participate in the presentation of their project proposal or learning output in school-based mini science fair at the end of the school term. One of the female Team 4 students DV will be elaborated as an 'exemplary case'. Due to time constraints, all the PBL-SI male students did not participate in the school-based mini science fair as their end-of-year school examination was held immediately before the school holiday. However, they managed to submit all the required assignments (included project proposal, portfolio, journal, CIT and SPSE) and tests (i.e. FIT, and other HOT and motivation tests) that were also given to PBL-SI female students (who completed their school examination one month before holidays).

Fostering Creativity through Investigative Activities using OER (Exemplary Cases)

After the male and female PBL-SI students sat for lower secondary public examination in the subsequent year (October 2009), they were also invited to participate in MAAYS e-research activities. Only Team 4 members [M(4/1/1-4)] are highlighted as an 'exemplary case' given their outstanding performances in completing all assigned tasks with evidences of enhanced HOT and motivation in PBL. This was reflected in one of the scientific journals of Team 4 members as provided below, in their subsequent investigation;

> …The problem is related to the weather and the type of earth surface. During the rain season, the houses in the lower land will face floods. We have taken the sample of flood's water to find the cleanliness of the water. From the investigation, we found that the water are so harmful. It is because it mix with variety of harmful substances. This show us that floods can give diseases. How do we identify and solve the problem?...
>
> [M(4/1/1-4), reflective journal]

From their review of literature through surfing references from the internet mainly from OER, they found that the parameters used for measuring the quality of water [whether it is drinkable (Class 1), usable for recreation (Class 2), semi-polluted (Class 3), polluted (Class 4) or very polluted (Class 5)] include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), pH, Total Suspended Solids (TSS) or Turbidity. Some of their references were referred from the official website of the Department of Environment (DOE) URL: http://www. doe.gov. my/webportal/en/info-umum/piawaian-dan-kriteria-kualiti-air-marin-malaysia/. They have chosen TSS or 'turbidity' as parameter for further investigation. The following discussions are extracted from the analysis of the coded responses using framework analysis on the project report and research proposal or plan (e.g. for mini science fair 2008, MAAYS 2010 and SSYS 2010) by exemplary cases:

Team 4 students acquired '***knowledge***' using metaskills to gain overview of facts and issues related to water to facilitate further investigation. They were able to demonstrate the organization of thinking and monitor their learning process by optimizing useful information or resource. Under literature review section of project report, they were able to systematically classify the vast amount of knowledge acquired into: '(a) Information from newspaper; (b) Recent issues related to project; (c) Study done by people; (d) Contaminants: Types, examples, definitions; (e) The effect of drinking contaminated water; (f) Disinfect contaminated water: Numerous types of methods; (g) Purification and preservation of drinking water: Methods to maintain water quality and quantity.' [Extracted from an exemplary project report by male students, as illustrated in the file uploaded onto SP3ACEMAN portal (http://forum.sp3aceman.net)].

Students working in teams were encouraged to 'think deeply', manifesting their metaskill to monitor/regulate their thinking within the complex PBL processes. They '*brainstorm*' ideas among themselves on causes and effects of 'flood' and 'pollution'.

For example, female Team 4 members explored 'ways to prevent flood' or minimize the damage caused by floods. From literature review on flood prevention, they found that there was a 'connection' between flood and 'river banks, flood wall or flood barriers'. Thus they formulated the hypothesis of 'The shallower the drain, the faster the water got overflowed' or 'The deeper the depth of river, the lesser the risk of flood will happen'. They had also set the dependent variable as 'overflow of water', independent variable as 'the depth of the container' and controlled variable as 'the volume or same amount of water used to test the overflow of water'. These formed the basis for investigative activities presented in mini science fair by the female students later.

'Inspiration' for investigation was acquired by reviewing literature on numerous water related issues. For example, from the review of the common water quality parameters by male Team 4 members, the 'improvisation' of project ideas resulted from collaborative decisions to solve problems in three problem cases focusing on 'turbidity'. A science project entitled 'Swift turbidity marker' was prepared by one Team 4 student guided by 'More Knowledgeable Others' (MKO) in a local university. The project is a new turbidity meter with a simplified functionality for rapid investigation of 10 different levels of turbidities from the range of Total Suspended Solids (TSS) between 0 to 500 mg/L. The research proposal 'An investigation on the turbidity levels of flood water that is harmful to human's health using Swift Turbidity Marker' was further adapted by three Team 4 members for MAAYS scientific blogging activities (focusing on topics, e.g. 'Values-based water education') as well as i2discovery proposal competition.

The students' project ideas were also selected for further 'development' into useful and practical applications for sustainable solutions of water related problems in local community. From lab activities, Team 4 male students found that turbidity could be measured by a turbidity tube via light passing through a glass/plastic tube or column of water and a 'cross' sign or a coin being put at the bottom. They used a pen to write a 'cross' sign on filter paper or a coin, put 500 ml of sample polluted river water (they have collected after the flood that happened in their school recently) in the beaker. Then they placed the filter paper at the bottom and paid attention to 'cross' sign until it could no longer be seen when water was filled. From literature, they also knew that high turbidity is normally resulted by high TSS. To ease the measuring process of turbidity, they had explored ways to design a user-friendly instrument guided by MKO. For example, the project entitled 'Swift turbidity marker (STM)' is a technological tool using Physics concepts related to 'Electronic and Optics'. This instrument entitled STM was designed to measure the turbid water samples with suspended particles (clay and silt) of grain size less than 63 μm. TSS from a combination of clay and silt were used in preparation of samples for experiments conducted as the source of turbidity.

Student researchers ensured that the TSS used was fine enough and that the particles were able to form a homogeneous solution or mixture with water (the precautionary measure they had made for their study). Optical components, i.e. detector (photodiode) and light source ['Light Emitting Diode' (LED)] used in this design was ensured to have an effective optical parameter at wavelength of 880 nm. This wavelength was the most efficient value stated by ISO7027 being used for turbidity measurement.

On the contrary, they found bigger grain size would cause a higher terminal settling velocity thus affecting the reading of actual TSS concentration. Whereas darker particle colour would cause more light to be absorbed rather than scattered, which may also affect the reading of turbidity. The Team 4 project team designed the STM with a simplified functionality for rapid investigation of 10 different levels of turbidities from the range of TSS between 0 to 500 mg/L, suitable for use to measure water of different qualities ranged from Class 1 to Class 5. The turbidity indicator was illustrated by a 10-bar LED display with every bar carrying turbidity resolution of 50mg/L. A *'straight forward design approach'* was introduced in the design of STM that eliminates the needs of complex amplification and algorithmic processing circuitry. Thus it produces a simpler version of turbidity meter that was cost effective or affordable for different levels of community with a variety of applications that require rapid turbidity reading (Mohd. Akram & Muhd. Ruzairie, 2010). This project was also used later to help measuring the turbidity level of 'drinkable and semi-polluted water', the focus areas of project proposal submitted to MAAYS '*i2discovery'* proposal competition by other teams.

Apart from the aforementioned five steps of creativity, one important stage to exemplify the output of creative product is the sharing and dissemination of findings through blended mode using OER effectively. The scientific research project was presented with unexpected winning of 'Best Research Report' awards in the 7th SSYS regional congress (March 2010). Subsequently the project team also won 'Champion' in Penang State Science Fair (August 2010) [as illustrated in *Figure 6*, URL: http://maays.net/2010/03/13/ssys-winners-list/] with '**E**valuation/exchange/exposure' being facilitated and disseminated through e-portals and forum sites (http://forum.sp3aceman.net). Team 4 student was invited to present in 'Project-based learning for science fair' workshop at Universiti Sains Malaysia (USM) Annual Science Carnival conducted by University's Museum and Gallery (Figure 7). Another presenter is the webmaster of MAAYS and SP3ACEMAN (*i.e.* the pilot sample of this PBL study in 2008) who was the first prize winner in the Penang State Science and Technology Carnival in 2009.

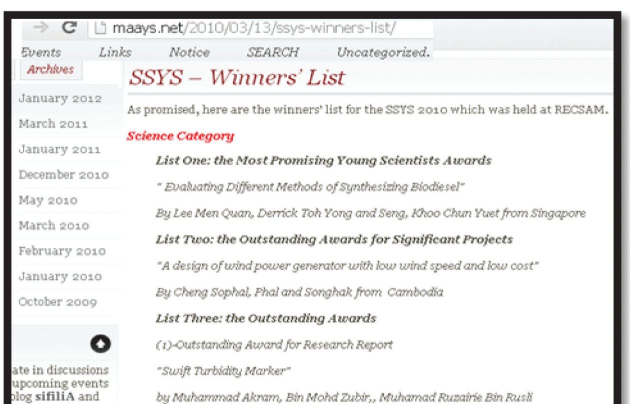

Figure 6 SSYS 2010 winners' list posted onto http://maays.net/2010/03/13/ssys-winners-list/

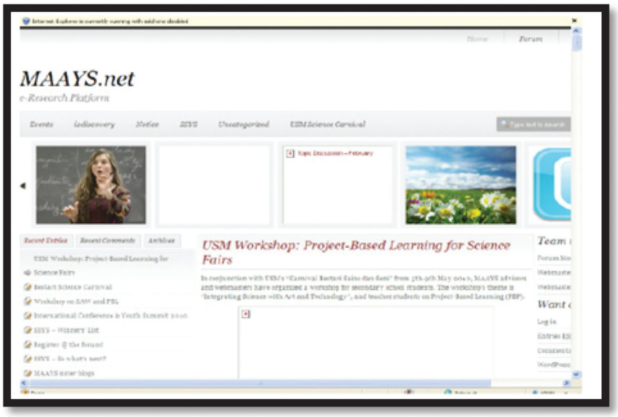

Figure 7 Exemplary students were invited to present in USM project-based learning workshop

The latter student had demonstrated high level of creativity and shared his learning experience using WordPress software as an example of OER to design web portals;

> Web designing is not like writing a book. A good website is no longer about putting up info. on the Internet, it is about being interactive and easily accessible to the user with ultimate goal that could help fostering creative discussions among on-line users. When a user lands on a website, it must be designed in such a way that the user intuitively knows his way around the website without lengthy tutorials/instructions....While creating OER we learnt how to think from the perspective of end users and create a dynamic process flow within the website to enhance the user experience.…We identified early on that OER had 2 major goals: first, to disseminate factual info. lucidly; second to facilitate discussions within and between the student and educators. With these goals in mind we designed an environment with cogent software, WordPress, as the back-ground, also incorporated interactive elements e.g. phpBB forum software, chatboxes, and instant messaging between users. To cope with ever increasing traffic and info…volume, the environment we employed was also designed to be easily scalable through the use of recyclable elements and creative css coding…
>
> (David Yong, webmaster 1, interviewed in April, 2011).

Another student who had also assisted in designing the two web-portals, had similar feelings and thought it is important to be empowered with the opportunity to explore various new technological tools in the digital era to foster creative potentials of young learners,

> I am glad to be given the opportunity to explore the WordPress platform, which was provided when I first started blogging on WordPress instead of the conventional Blogger by Google. The forum board powered by phpBB also gives me valuable experience as one OER for web-designing. This is an extension of my previous learning in the use of ICT tools to develop webportals using innovative ways. I was able to relate my

> existing knowledge and see the patterns of designing web using the existing software. ...The most challenging task is the design revamp and modification of the WordPress site theme which requires a certain knowledge in coding, and I had explored long hours to get the solution of the design, similarly with other web-designing features that require new skills. Thus I had trained to become a more flexible and fluent thinker, able to solve problems heuristically using innovative ideas when I was faced with new tasks…
>
> (Chee Yi, webmaster 2, interviewed in April, 2011).

In brief, both web-designers had undergone the 'knowledge, thinking, incubation, inspiration and development' processes of creativity, became flexible and fluent thinkers with the essential creative traits being fostered during the process of their exploratory activities to design web-pages using OER effectively. Before the assigned tasks, they had some basic 'knowledge' in web-designing and coding. They were also able to see the patterns and 'think' deeply while they faced the moment of revamping or modifying the site theme. There was an 'incubation' stage when they had to explore long hours, did some literature search and discussed with advisors or other experts to get the solution of the design. With their prior knowledge and experience, they gained 'inspiration' and finally became successful in the 'development' of the portals.

CONCLUSION

This article illustrates 'within-case' analyses of Team 4 secondary students' participation in a specially designed PBL programme integrating ICT with elaboration on five exemplary cases including effective use of OER for e-research/e-learning and exchange activities facilitated through SP3ACEMAN and MAAYS portals. Although the study had been successfully completed within the years of 2008 to 2011, upon reflection there were still some pedagogical issues to be deliberated. For example, there are possible R&D activities concerning this programme which are worth pondering in order to explore better ways to leverage on the potential of OER and promote thinking skills using PBL through blended learning activities.

Discussion on Pedagogical Issues due to Limitations and Significance of Study

As this research involved 'purposive random' sampling technique (Creswell, 2009), the cases as elaborated here were only limited to reporting findings within the periods of 2007 to 2011, with the data extracted from the studies conducted in secondary school within the local context. Since the PBL programme incorporated ICT tools using OER effectively, the constraints faced in terms of time and accessibility to internet or availability of ICT facilities are obviously the limitations for smooth conduct of studies. Time constraints faced was due to the fact that the study was conducted at the second half of year 2008 when many important public and school examinations were held. There were also pedagogical issues for technology enhanced learning. For example, the ideal aspiration of self-directed/self-paced/self-accessed learning to participate in e-learning programme could not be facilitated without stable internet connection with technical support. Hence during the pilot and actual studies, the researcher had anticipated some problems that may be faced. Apart from downloading the OER digital materials as off-line resources, the researcher also shared the PBL-SI support tools that were compiled with other resources into CD-ROMs. Before the school-based mini science fair, some students who were good in ICT were also selected to explore digital resources and prepare posters using computers in teacher's room. Of course, there were also students who had access to computer and internet facilities at home. Apart from encouraging these students to carry out self-directed/self-paced/self-accessed learning at home to cultivate their creative potentials, the researcher had also invited them to do real time chats through MSN (another useful OER) so that follow-up activities to advise them on PBA/PBL could be facilitated on-line more effectively. In fact two of the selected pilot study students (who had responded to interviews as reported) were involved in the development of MAAYS and SP3ACEMAN portals after their public exams in 2008 and 2010 with advice and guidance on the content materials given by the researchers and founders of both portals through chatting with them. As such, the use of OER on-line chatting tool such as MSN was also proven to be effective to foster creativity.

Implications and Recommendations for Future Research

This PBL-SI study revealed that generally students' HOT skills especially creativity was enhanced after their participation with some 'more/moderately successful' students (e.g. 'exemplary case' as elaborated) also showed enhanced motivation and prolonged interest after the study. These students participated and won in international competitions related to PBA or PBL. Hence, this study revealed the feasibility of e-learning programmes facilitated through SP3ACEMAN and MAAYS to enhance science investigation, scientific/thinking skills and ability to participate in the communication or e-forum activities through highly interactive digital learning environments that leveraged on effective use of OER.

The following observations made (throughout piloting of FIT and PBL-SI study using FIT to evaluate creativity) need further attention with reflections on implications. Pilot study students showed high interest and enjoyed doing FIT (or what they defined as IQ test) which might be as different types of questions they have not normally taken in the school examinations. This showed that students were also motivated to do activities they were interested in, for example involved actively in e-portals that promote PBL as evidenced in this study. Thus teachers should consider constantly challenging the thinking skills of such types of students, perhaps leveraging on the available OER through the blended learning platforms. Teachers should not merely introduce students with static curriculum focusing on school text book which may be perceived by such types of students as monotonous tasks as they may not be attracted to explore further.

Since the students involved in the FIT pilot studies showed great interest in doing FIT, more adaptation of validated items to evaluate fluid intelligence or creativity should be made to raise students' interest in studies and to train their thinking skills. It is also recommended that more research should be conducted to include the evaluation of students' fluid intelligence before implementation of any curriculum to teach thinking skills and conceptual/procedural knowledge, possibly facilitated through ICT tools or e-learning mode with effective use of OER.

In fact, increasing emphasis on student-centred PBA and PBL using blended learning platforms to promote thinking skills was seen in numerous developing and developed countries as reported by Tey *et al*. (2010) from Singapore that is among the highest performing country for international comparative studies such as the Trends in International Mathematics and Science Study (TIMSS) and The Programme for International Student Assessment (PISA). The cross-sectional study on TIMSS 2007 by Corrienna, Hazura and Pagunsan (2012) also showed that computer use was positively associated with high student achievement. Their findings revealed that students who indicated that they use computers both at home and in the school were those with highest science achievement. In another study by Conner *et al*. (2013) to evaluate students' performance for scientific literacy, reading and thinking skills in PISA 2009, it was found that in high performing country such as New Zealand, there is a much greater emphasis on early years' education as well as students gaining ICT and other competencies. This is reflected in the national assessment system (including informal assessment) and the use of e-portfolios for showcasing learning in science and mathematics. The research conducted at Finland as one of the highest performing countries in PISA also revealed that inquiry-based learning approaches in science/mathematics curriculum were very much emphasized at early education (Sanders, 2009). Hence, it is timely that this study of a specially designed PBL-SI programme integrating ICT with evidences to foster thinking skills among secondary school students will contribute to one way or another, the aspiration to inspire further research to produce innovative young generation as driving force for the development of nation.

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