Making the Challenges Possible through Education Superhighway: A pilot project to motivate young learners towards Problem-based Learning (PBL) using technological tools

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Abstract:

In light of the attention to project/problem-based learning (PBL), it is noted that PBL has been used in science education for gifted students for many years (Sitkoff, 1988). Literature revealed that a renewed movement toward student-centred approaches has become possible instructional settings in which students define their own content and pursue learning based on own interests. But this opportunity is limited to high-achievers (Betrus, 2007). This paper reports on the author's experience in devising a support tool to motivate learners in technology enhanced PBL. It outlines various technological challenges and provides possible solutions to minimize the barriers faced towards Education for All (EFA). Emphasis was made on how could technological tools facilitate problem-based science learning via the integration of multimedia in PBL. Anchored on social constructivist theoretical framework, a POSITIVE support tool for PBL was devised as part of the content for "**S**cience **P**roject/Problem-based **A**ctivities in**C**orporating **E**xperiment **MAN**agement" ($SP^2ACEMAN$). It was initially compiled as off-line resource material to provide comprehensive guide and scaffolded activities for students who were mostly beginners for PBL. Pilot studies were also conducted in science classes participated by two groups of secondary students ages between 12 to 15 years. Prior to PBL, pre-tests including evaluation of students' values/attitudes and motivation were conducted and data collected via off-line resource materials using the items devised based on the rubric guide as PBL support tool. Students' post-tests responses from survey were also collected and analyzed via paired sample t-test. The analysis of students' qualitative feedback on the effects of support tool with coded responses was used as references for the refinement of tool and to inform further practice. It is envisaged that at the end of pilot study, the support tool could be made accessible for a wider group of participation in technology enhanced PBL. (296 words)

Keywords: Technology enhanced learning, Project/Problem-based Learning (PBL), pilot study, social constructivist framework, rubric guide, support tool, networking

INTRODUCTION

Developing investigative projects to be presented in science fairs has more often been regarded as a privilege activity given to high-achieving learners due to the more challenging tasks in problem-solving curriculum and investigative project or problem-based learning (PBL) as evidenced in studies (Valencia, 1996; Ng, 2002; Ng, 2005). In light of the recent attention to PBL, it is noted that PBL has been used in science education for gifted students for many years (Sitkoff, 1988; Gallagher & Stepien, 1996). This issue about equitable participation of PBL by all students was raised by an audience during the paper presentation by the author (Ng, et al., 2006) in 10th APEID conference (6th to 8th December 2006) organized by UNESCO Bangkok with the theme *Education for Sustainable Development* (ESD). Apparently there is a gap in between theory and practice whereby students are not given equal opportunities to participate in numerous educational initiatives. For example, Betrus (2007) stated that a renewed movement toward *learner-centered approaches* in education has become possible instructional settings in which students define their own content, and pursue learning based on their own interests. But this opportunity is limited to *high-achievers* or *high-achieving* students. Moreover, most educational practices seem to place emphasis on cognitive development and neglect the affective domains. Redressing this learning discrepancy by giving due emphasis to inculcating values and motivation among students for science investigative activity is also necessary to reverse the undesirable lopsided educational trend.

Background and objectives of the study

This paper reports part of a bigger scale of study involving the use of ICT tools to support Project/Problem-based Learning (PBL). The main aim of this article is to elaborate on the author's experience in devising a support tool to motivate wider groups of learners in technology enhanced science PBL with the following objectives:

- To outline various technological challenges and provide perspectives on possible solutions to minimize the barriers faced towards Education for All (EFA).
- To report on the pilot studies conducted with the procedures to establish reliability and validity of the support/evaluation tools devised for scaffolded instructions to facilitate PBL.

- To report on the evidences of students' enhanced values and motivation in technology enhanced PBL.

The following section explores literature related to framework of study and technology enhanced science pedagogies via ICT tools that facilitate problem-based learning (PBL).

LITERATURE REVIEW

Constructivism and social constructivist learning theories as research framework

The key principles of constructivism supported that learners build personal interpretation of the world based on experiences and interactions with knowledge that is embedded in the learning context in which it is used. Learning which is viewed from *social constructivism* or *social learning* theories of situated cognition focuses on learners' prior knowledge and how they construct their understanding based on their *contexts* or learning culture. The theories supported learning as a social and cultural activity mediated by the social and environmental factors around the learners that stimulated their learning so as growth occurs in cognitive, psychomotor and affective domains.

Constructivist theory recognizes that *motivation* is influenced by how *interesting* and relevant the children perceive the activities and information, which are indirectly influenced by the *values* and *attitudes* one's possessed in learning (Atwater, 1994 in Gabel, 1994, p.564). The instructional or learning strategies that are proposed under constructivism include constructivist teaching, collaborative learning in Community of Practice (CoP) (Lave & Wenger, 1991) and Problem-based Learning (PBL) (Fogarty, 1998). In research reported by Helgeson (1994), most, but not all cases, using inquiry-oriented curricula resulted in significant gains in problem-solving skills, in achievement, motivation and attitudes toward science (Helgeson, 1994 in Gabel, 1994).

Learning involving 'whole science' experience consists of the development of children's attitudes, process skills and the construction of useful ideas or products. Children's experience can stimulate their curiosity (or *attitudes*) which can *motivate* them to develop new process skills to be used to construct the products of science. The field of science education brings learners, science and society together so that growth occurs in cognitive, psychomotor and affective domains. The cognitive (or learning) domain involves the acquisition of facts and concepts, along with the development of problem-solving and reasoning skills. The psychomotor (or doing) domain involves the development of physical and dexterity skills. The affective (or feeling) domain includes a host of constructs, e.g. attitudes, values, beliefs, opinions, interests, and motivation (Simpson, et al., 1994 in Gabel, 1994). PBL is an inquiry-oriented approach covering all the abovementioned three, especially cognitive and affective domains.

Technology enhanced pedagogies that facilitate project or problem-based learning (PBL)

Successful learning enriches the experience universe and stimulates further inquiry learning possibly supported by non-digital or digital resources. The output or product of problem-solving activities and PBL with possible ICT integration 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, p.1). Research shows that projects in the sciences can build from students' questions, and when well-guided by mentors, provide motivating and effective contexts for the acquisitions of research skills and scientific understanding (Fogarty, 1998).

Situational approach is a commonly used teaching pedagogy that incorporates social constructivist ways of teaching with emphasis on problem-solving in everyday life. This type of learning is also elaborated as *social mediation* with *participatory knowledge construction* in which interaction among group members (e.g. peer group) serves as the socially shared vehicles of thought with possible support or coach from facilitator (e.g. teacher) that helps an individual to learn. Social mediation could be elaborated as, by *cultural scaffolding* [in which the emphasis is on the use of non-digital or digital resources or tools and artifacts e.g. books and technology in mediating learning] and with the *social entity as a learning system* that may bring about changes in its underlying *values*, beliefs, culture and norms (McConnell, 2000 in Ng & Fong, 2004). Hmelo-Silver, Duncan and Chinn (2007) argued that PBL is highly scaffolded with evidences demonstrating that it is a powerful and effective model of learning. *Scaffolding* is an instructional strategy (e.g. via use of support or evaluation tool) that is useful to minimize the barriers of PBL. It involves supporting the beginners or novice learners for PBL by limiting the complexities of the learning context. Those limits will be gradually removed as the learners gain the knowledge, skills and confidence to cope with the full complexity of the context in problem scenario. Feedback will also be given to ensure guidance provided was able to reduce Zone of Proximal Development (ZPD). ZPD is a concept defined by Vygotsky (1978) to represent the difference of the gap or difference between a child's independent problem-solving activity and the level of problem-solving possible under the guidance of an adult, a more capable peer or more knowledgeable others (MKO) (McCormick & Paechter, 1999). Feedback (that was considered number one influence on student learning and achievement according to the recent research findings) is an important aspect for social constructivist approaches (Hattie, 2003 in Groves, 2009).

Technology plays an important role in the recent years to facilitate science learning. Cognitively-guided research in science education shows that teacher-centred pedagogy with lecture and demonstration is not effective at securing student's understanding in subject matter. Research in science learning has also indicated that learners and teachers need highly interactive conversational environments around media-rich artifacts to provide common grounds for fostering learning communications (Pea, 1995). Findings from research revealed that integrating computer-based learning (CBL) in teaching-learning activities has been effective in allowing students to learn at their own pace. Another distinct mode of instruction to promote science and technology education which can reach wider audiences is the introduction of distance learning incorporating various innovative web-based applications e.g. virtual learning. Traditional distance education inherits the transmission model of instruction [in which technological tools are used to transfer instruction in a more engaging fashion and to larger numbers of learners]. Phone lines, satellite links and microwaves will be used to transmit static knowledge to wider audiences, with minimal opportunities for highly interactive conversations among instructors or learners (Pea, 1995) and other supporting infrastructures such as the physical resources of hardware, software, telecommunications as well as alternative delivery systems (ADS). According to Szabo (1996),

> …*Alternative Delivery Systems (ADS) basically provide different ways of organising and delivering instruction (education and training) from the conventional lecture format in which information is transmitted to learners through heavy use of interactive multimedia (computers, media and telecommunications)* ... (Szabo, 1996; p.52).

Among the technological innovations or education network initiatives using that distance education mode are the online student service applications, e-Learning Management System (eLMS), interactive tutorial sessions and professional advice with various electronic outreach, tele/video conferencing, e-mail, IRQ (Interrupt Request) or ICQ (I seek you), IRC (Internet Relay Chat), MOO (MUD Object Oriented, i.e. an online, text-based, real-time virtual reality environment); basic voice telephone service, voicemail systems, wireless networks and enhanced modem services that may be accessible to various parts outside the institution.

RESEARCH METHODOLOGY AND TECHNOLOGY ENHANCED PBL

This section will discuss the identification of key areas required in a comprehensive model with justification for teaching and assessing PBL among underachievers in the CoP supported by e-learning platform. Elaboration will be made on how could technological tools facilitate problem-based science learning via the integration of ICT tools or multimedia with research evidences.

Pilot studies on the development and validation of tools to facilitate PBL in case study schools

The first step in developing a support tool involves summarizing the essential elements of PBL with an acronym 'POSITIVE' in the checklist as support tool devised to guide teachers and underachievers with low motivation in science when implementing PBL activities in CoP. Prior to the pilot studies of POSITIVE tool, the following objectives are identified:

- To guide the reflective practice of teachers as core member in Community of Practice (CoP) towards more in-depth understanding before they introduce and assess PBL among learners especially underachievers.
- To support teachers to *scaffold* the learners' practice in PBL, continually adjust the level of their help in response to learners' level of performance with feedback of results, thereby instill the skills necessary for their independent problem-solving according to ZPD theory.

Anchored on social constructivist theoretical framework, a POSITIVE support tool for PBL was devised as part of the content for "Science Project/Problem-based Activities inCorporating Experiment MANagement" ($SP^2ACEMAN$). Due to the constraints faced in accessing to Internet facilities, this tool was initially compiled as off-line and printed resource material (attached as checklist or guide for students in their reflective journals) to provide comprehensive guide for students who were mostly novice or beginners for PBL.

According to this checklist, *'**P**lanning and **O**bjectives'* are considered as two important components. This is because literature revealed that "*setting clear learning objectives at the start of a lesson and encouraging pupils to assess their own understanding following each lesson*" (Spavold, 2005, p.119) was effective to enhance the *motivation* of students who appeared to be more engaged throughout the lessons. Various cognitive/psychomotor and affective factors contributing to effective learning are considered in the tool. It was also assumed that underachievers who have participated in CoP and could successfully design investigative projects guided by More Knowledgeable Others (MKO) in CoP would develop beliefs about the extent to which their tasks in PBL are useful and enjoyable according to '*Expectancy-Value Theory*' (Palmer, 2007). Thus some motivational remarks (refer printscreen of the index page of the off-line webpage e-learning platform in ***Figure 2***) to encourage 'POSITIVE' thinking or attitude towards problem-solving practices among underachievers are given in the checklist. The meaning of each alphabet in the 'POSITIVE' acronym that is related to the features of PBL is elaborated as below:

P [***Planning*** the ***Procedures*** in carrying out thoughtfully planned PBL teaching learning ***process***]

O [***Objectives*** and ***Organization*** considering diverse learning styles and socio-cultural background]

S [***Skills*** in experimentation, e.g. scientific (process/manipulative) and ICT or technology skills]

I [***Information***/data gathering and resources/facilities procurement via cooperative role taking]

T [***Training*** and ***Transfer*** of learning via Higher Order Thinking Skills (HOTS)]

I [***Involvement*** actively in various context, ***Incorporating*** pedagogical-content knowledge (PCK)]

V [***Values*** emphasis and inculcation of positive attitudes/interests/motivation (AIM) towards Science, Technology, Environment, Society (STES)]

E [***Evaluation***/assessment, ***Exchange*** of ideas/experiences, ***Enrichment***, ***Everlasting Exposure***]

This checklist outlined the essential elements of PBL with the translation of the researcher's knowledge from literature review and understanding on various aspects of problem-solving behaviours including the mastery of *conceptual* and *procedural* knowledge in PBL. Apart from the aforementioned, the respondents were also requested, in the checklist, to reflect on their learning via developing scientific/ICT skills (**S**); gather **I**nformation via non-digital/digital mode of resource procurement (**I**); **T**ransfer their learning via higher order or critical/creative thinking, metacognitive thinking, decision making and problem-solving skills (**T**) that are related to *cognitive/psychomotor* aspects. Moreover, the aspect of '*values*' emphasis and interest in STES via PBL (**V**), i.e. *affective* domain of problem-solving behaviours, an area of research that is very much neglected, as reviewed in literature, is also included. Thus this study will cover three vital aspects of problem-solving in PBL, i.e. cognitive/psychomotor and affective domains, with evaluation/exchange supported by e-learning platform.

In addition to validating POSITIVE support tool and evaluation tools using questionnaires (on values and motivation) among in-service teachers via three cycles of reflective practices by the researcher (Ng, 2008), pilot studies were also conducted in science classes via ICT integration participated by two groups of secondary students ages between 12 to 15 years. Prior to PBL activities in the two case study schools (including students who were also involved in the pilot studies of the support and evaluation tools), pre-tests were conducted and data collected via off-line resource materials using the items devised based on the rubric guide as PBL support tool. Students' post-tests responses from the survey were also collected and analyzed via paired sample t-test to be reported in the following section.

Technology enhanced Project/Problem-based Learning (PBL) via SP^{2}ACEMAN portal

In the web-based programme entitled **S**cience **P**roject/Problem-based **A**ctivities in**C**orporating **E**xperiments **MAN**agement (SP^{2}ACEMAN) that is developed as e-learning platform to monitor and sustain PBL activities (see ***Figure 2***), the following features were proposed with rationales based on review of the aforementioned theoretical framework:

1. To encourage PBL among learners with diverse levels of achievement following the off-line assessment based on their prior knowledge taking into consideration the diversity of students' background and experiences advocated in this study which is anchored on social-constructivist and socio-cultural theoretical framework (refer flowchart in ***Figure 1***).
2. To promote gradually paced problem-solving activities with skills enhancement trainings and use of resources or activities at various levels of difficulties being monitored using POSITIVE checklist before students are challenged with difficult tasks in PBL. The reason is that PBL was perceived as difficult and quite often underachievers were not selected to be involved.
3. To explore students' entry levels and *attitudes/motivation* using off-line assessment (including 'values/attitudes' and 'interest/motivation' questionnaires, findings to be discussed in the following section). Thereby this facilitates cooperative and heterogeneous ability grouping (Cagnole, et al., 2004), with the forming of CoP according to socio-culturalist perspectives of situated and mixed-ability learning. Students obtain guided participation from teacher facilitator and shared cognition with peers and experts. With numerous project-based learning activities suggested in various on-line learning programmes, e.g. "Science across the World" (SAW) (Ng & Fong, 2004) with evidences as reported by Ng, Tan and Toh (2007), students will expand their learning community by exchanging findings with students from other parts of the world.
4. To include in the e-platform more suggested PBL activities via interdisciplinary and cross-curricular approaches incorporating various topics suggested under numerous on-line project-based learning portals. For example, in '*Drinking Water*' topic introduced in SAW programme, students could be further encouraged to, e.g. solve problems of water crisis in society; design simple water storage devices from waste materials; recycle water by converting waste water into drinking water; combat water pollution incorporating knowledge in Biology, Chemistry, Physics, Technology, to name a few. They could also collect/analyze data, calculate statistical findings and track the research results of activities in solving water pollution using innovative technologies, e.g. SPSS, electronic LED device, Google Earth, to name a few. Whereas, in '*Domestic Waste*' topic, students were only encouraged to do a *survey research* on topics for debates, e.g. 'who is responsible for waste disposal' which can be a *simple project*. In fact, PBL should also be incorporated whereby students are requested to brainstorm, e.g. on the possibilities of recycling domestic waste into renewable energy as researched by industrial scientists. Students can also expand their understanding to solve real-life problems faced in society, e.g. with plastic waste that indirectly affect water or environmental pollution. Thus, technology enhanced PBL provide rooms for more interdisciplinary/cross-curricular studies.

The following page provides a brief illustration of the flowchart of technology supported science PBL and "**S**cience **P**roject/Problem-based **A**ctivities in**C**orporating **E**xperiment **MAN**agement" (SP^{2}ACEMAN) on-line learning portal to facilitate PBL.

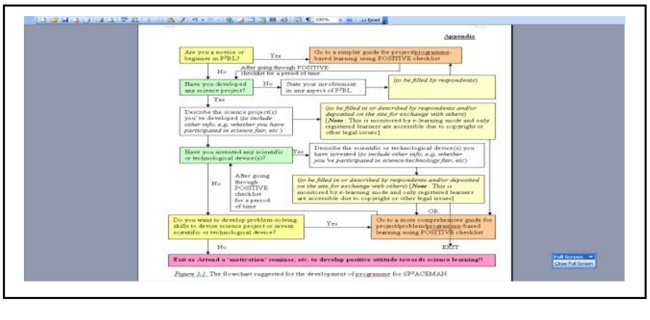

Figure 1.
Suggested flow chart for the implementation of technology support PBL

Figure 2.
Index page of the off-line e-learning platform with motivational remarks to promote Project/problem-based learning (PBL) among underachievers in the Community of Practice (CoP)

DATA COLLECTION AND ANALYSIS OF FINDINGS

A secondary school anonymously named as School A was selected for case study via convenience sampling, i.e. one that is chosen for practical reasons and convenient for use. It is also a non-representative or non-random sample (Cohen & Swerdlik, 2002). Nevertheless one would normally be willing to generalize the results to other similar schools and children (Smith & Davis, 2001). The research involving convenience sampling is primarily concerned with relationships within the groups studied rather than with the attitudes of the larger group from which the sample is drawn. This kind of research is designed to answer the question, e.g. 'How does the dependent variable change if the independent variable is changed?' It is not designed to ask, e.g. 'How widespread is this characteristic within the population?' (Lewin, 1979). It is hoped to espouse exemplary social constructivist approaches to PBL practice in transforming the identity of underachievers with evidences of their enhanced conceptual or procedural knowledge, values/attitudes and interest/motivation for technology enhanced problem-based science learning in the CoP supported by e-platform with PBL tool via POSITIVE guide. More elaboration on how the PBL tool support science learning in cognitive/psychomotor and affective domains will be made with triangulated findings. For example, students' reflective journal, portfolio and project proposal serve as alternative assessments for the PBL skills required in '**Pl**anning the Procedures' with '**O**bjectives and Organization' of learning and acquiring '**I**nformation' to support their PBL, and so forth.

About 5 students and 2 teachers (including sample Teacher A who had attended in-service training on PBL conducted by the author) were chosen for more in-depth interviews on the evaluation of the use of tools in technology enhanced PBL. Twenty-five Form 4 students taught by Teacher A were selected from School A which is a non-premier school from rural area. These students were quite weak in academic performance and were considered as deviant case or non-typical subject. Case study was conducted in this school to illuminate the effect of the implementation of project/problem-based learning (PBL). O*bservations* were made on the characteristics of teachers' practice and students' interactions to identify critical attributes for effective implementation of technology enhanced PBL incorporating e.g SAW. on-line learning programme. Through informal *interviews*, the case study teachers participated in SAW programme had shared their experiences on the success and problems faced during the implementation. Apart from data collection activities involving observation, interviews and documentary analysis, findings from survey questionnaires being administered before and after PBL were also analyzed and will be discussed in the following section.

Prior to the aforementioned case study research activities in School A from May 2005 until March 2006, a series of pilot studies involving mainly the validation of POSITIVE tool and two evaluation questionnaires (to be administered before and after PBL) were conducted within the periods of 13 February 2004 to 7 February 2005. 'Pilot' testing refers to preliminary, exploratory testing that is done prior to the complete or 'real' research. During this stage, a small samples were tested and in-depth interviews were used to help determine the type of questions that should appear on the final survey instrument (Smith & Davis, 2001).

The first evaluation questionnaire on "Students' values/attitudes towards PBL and the aspects of STES education" (*QVAPblSTES*) was adapted from two questionnaires, namely, Questionnaire on the students' scientific and problem-solving attitudes (QScPbsA) and Questionnaire on the students' values towards STES education (QVAIMB). The reliability analysis for pilot study (19/4/05) was Cronbach Alpha (CA)=0.6582, and for pre-test (27/5/05) an acceptable level of internal reliability (CA=0.8364) was indicated. The following are the constructs identified in this instrument at the end of pilot studies (Ng, 2008, pp.93-100):

(i) *Values sense/civic-mindedness towards STES and their interactions*, e.g.Items No.***8 & 9***.

(ii) *Understanding science/technology and its impact on environment/society*, e.g. Items No.***4, 5 & 6***.

(iii) *Incorporating scientific/problem-solving skills in challenging activities*, e.g.Items No.***12***.

(iv) *Active thinking, doing and creative problem-solving*, e.g.Items No.***2,7,11,13,14,15 & 18***.

(v) *Transfer of knowledge in relevant/real life contextual-learning,* e.g.Items No.***1,10 & 17***.

The reliability analysis for the second questionnaire on "Students' Locus of Control" (*QLOC*) after pre-test (27/5/05) indicated an overall acceptable level (CA=0.7059) with the following dimensions of items that were established based on factor loadings by varimax rotation:

(i) ***Individual self-esteem/self-efficacy*** (*Intrinsic/internal LOC*) vs. Extrinsic belief system or factors influencing achievement (*Extrinsic/external LOC*), e.g. Items No.***3, 7 & 12***.

(ii) ***Personal skill/effort*** (*Intrinsic/internal LOC*) vs. Influenced by powerful others/chance/ fate (*Extrinsic/external LOC*), e.g. Items No.***1 & 5***.

(iii) ***Individual coping ability*** (*Intrinsic/internal LOC*) vs. Assistance given by others, external factors or resources (*Extrinsic/external LOC*), e.g. Items No.***2, 4 & 6***.

(iv) ***Internal control/ability*** (*Intrinsic/internal LOC*) vs. External task related difficulty in learning or other factor (*Extrinsic/external LOC*), e.g.Items No.***8, 9 & 11***.

(Ng, 2008, pp.101-105)

As stated, apart from survey questionnaires, evaluation data was also collected from observation, interviews and documentary analysis. The POSITIVE *checklist* was also adapted from the *implementation indicators* of student-centred learning, i.e. an approach that requires both the students and teachers to share in the responsibility, delivery and evaluation process of programme. The *observation indicators* addressed the needs to give students empowerment of learning so that they become independent, self-directed and lifelong learners who will take responsibility and ownership for their learning. Students were required to demonstrate greater decision-making and *problem-solving skills*. Teachers were expected to operate as coach, mentor, facilitator and tutor. The teaching approach used was determined by appraisal of needs, interests and individual learning styles (Board of Education for the City of York, 1989). During case study, students' science learning was *observed* using video recording devices and/or observational instrument guided by POSITIVE tool. Background information of students, teachers, classroom and orientation towards learning were recorded, including evaluation, control, decision making and tension-management in technology enhanced PBL.

Research findings on students' feedback and evidences of their enhanced values/motivation

The following are some qualitative feedback about project team members' PBL experiences using POSITIVE support tool as extracted from their reflective journal, folio and off-line data:

> *…I feel happy because the portfolio help me a lot in the early experience/preparation before the real interpretation (**P**lanning/Preparation);…This kind of experiment helps me a lot in remember the facts in science subjects (**O**bjectives/**O**rganization considering learning styles); …I can develop hypothesis, draw a new picture about science that I haven't seen before…I can learn a lot on scientific skills… (**S**kill);…By collecting picture and information, I was able to build the real concept (**I**nformation);…When I did this folio, I have learnt various things regarding vitamine, balanced diet, the effect of taking, etc. (**T**raining/Transfer); By doing the folio, I have obtained a lot of info. from textbook, magazines, etc. (**I**nvolvement);…Because the subjects teach me how the connection in world something people do know…because it can cope with my daily life…we can learn how our nature can work with human being…Interesting becoz it makes sense to me…(**V**alue/interest);… I become more confident when I speak to the public…this program improve my English (**E**valuation/Exchange)…*
>
> (Selected feedback from students in case study school 1, August 2005 to April 2006; Extracted from Ng, 2008, pp.143 to 163)

Generally, students showed positive attitude towards various scaffolded instructions for PBL with change of perception towards self and 'identity' from the aspects of scientific attitude and technological capabilities. They were quite excited with the interactive activities using ICT which was rather different from the traditional transmissive approach of science teaching.

> *…Before PBL, I was weak to solve problem related subjects….After PBL,…I get a golden opportunity to increase knowledge about environment;…Before PBL, not confident to make experiment on my own;…After, felt confident to do experiment…even do it on my own;…Because of how interesting the teacher teachs me;…Easy to understand…I am realize that it is interesting, motivated and would like to learn for deeper understanding without much needing teachers to push me to do;…The program of PBL encourage me to study more about science;…Very exciting and adventures subject;…I like all science activities in computer;…Yes, I do as it may help me to think for a way to solve something logically;..I like to do a lot more of the activities because I like challenging participation especially biology;…More time in the computer lab;…Because a lot of…activities can make science very interesting to learn;…Science answers the questions I have in my mind about how things on earth go around;…After PBL, I think I am much more scientific, I would like to do experiments before coming to a conclusion;…I didn't get to learn from text book so many new things…I become a reflective learner like scientists…Science…provides opportunities to think creatively while doing investigation…Science is one way to understand nature…be proactive..*
>
> (Selected feedback from students in case study school 1, November 2006;
> Extracted from Ng, 2008, pp.168 to 174)

Triangulated findings from quantitative data were also obtained from pre- and post-PBL survey questionnaires. There were evidences of '*students' enhanced perceived levels of values and attitudes towards PBL with related aspects of Science, Technology, Environment, Society (STES) education*' in almost all items identified in *QVAPblSTES* questionnaire. Among the questionnaire items, the three highest post-test mean scores among the sample students were '*It is important to preserve the trees in the environment* (4.74), *It is important for us to have civic mindedness in the society where we live* (4.71) and *My understanding in science and its interaction with technology and environment will be useful to me when I leave school* (4.54)'. Upon analysis, it was found that these three items got direct meaning of linking science with environment and society. As the science topic chosen for PBL throughout the entire study was 'Nutrition/Biotechnology' and students had gained much exposure on STES education, this may be the reason why students scored averagely higher than other items.

However, there were relatively low t-values ranged from 0.552 to 4.592. Moreover, only six (6) out of seventeen (17) items displayed the significant improvement in mean scores (at $p<0.05$ or 95% confidence interval of the difference) when comparing the students' pre- and post-tests scores. Students also did not show improvement in the mean score for one of the negative item No. 13, '*I find lecture style of teaching MORE challenging and interesting than project/problem-based learning*'. The mean score for this item (i.e. 3.05) was also the lowest among the students' post-tests scores. The reason for this may be that the sentence was constructed in negative form which may have caused confusion among them. Moreover, there was still a great preference of students towards lecture style of teaching in the Eastern culture of prevailing teacher-centred approaches learning contexts. No doubt the case study students enjoyed PBL ways of learning which were rather new and exciting for them, the constraints faced during intervention activities such as time and facilities (especially ICT support) had also caused some disappointments among them. This may be the reason why they did not really find PBL supported via ICT tools as interesting as lecture style of science teaching.

There were evidences of '*students' enhanced perceived levels of motivation as measured from internal locus of control*' in almost all items identified in *QLOC* questionnaire except item No.10. The trends of improvement were quite satisfactory with most items showed significant improvement in mean scores (at $p<0.05$ or 95% confidence interval of the difference) when comparing the students' pre- and post-tests scores. However, there was again average t-value ranged from 0.415 to 4.561. Moreover, students' showed enhanced motivational traits which were quite general. For example, among the questionnaire items, the three highest post-test mean scores among the sample students were '*You can have a successful career in science if you work hard enough* (4.55), *You always think that getting along with people is a skill that can be learnt* (4.42) and *You believe that you can convince others if you are right* (4.33)'. Upon reflection, these three items were considered rather general and did not really reflect the mastery of scientific skills after PBL intervention (e.g. '…good at PBL science learning…' as phrased in item 5; '…persist on solving scientific problems…' as phrased in item 11; to name a few). This may be due to their lack of prior knowledge in science as most of them were underachievers. Within rather short duration of PBL intervention, the researcher should not have high expectation towards any vast improvement in their motivation or confidence in various scientific problem-solving activities.

CONCLUSION

Limitations and significance of study

The constraints faced in terms of time and accessibility to Internet facilities obviously are two main stumbling blocks for this study to be conducted smoothly. However, the positive feedback obtained from the research samples especially on the use of POSITIVE support tool to facilitate PBL had indeed increased the confidence of the researcher to further investigate the effects of PBL on students' motivation and thinking skills in the subsequent study. Due to the inavailability of computer facilities (especially in two case study schools identified by the researcher in the subsequent studies), the research on the effects of PBL was mainly conducted using off-line resource materials with face-to-face mode of interactions. Nevertheless, the pilot study as reported in this paper was successfully conducted with evidences of students' enhanced values and motivation as reflected from the analysis of questionnaires before and after the implementation of PBL. Most of them felt that it was easy to understand science project/problem-based learning (PBL) processes using the scaffolded instructions guided by POSITIVE tool. The majority of them also felt motivated to pursue investigative activities and future pursuance of science related studies or career. Moreover, four students who were selected to participate in 5^{th} "Search for SEAMEO Young Scientists" (SSYS) regional congress had also gained enriched experience in the '*Young Scientists' and Innovative Educators' Networking*' workshop (that was held on 9/3/2006), with on-line registration and web-forum activities in the website of '*Malaysian Academy of the Advancement of Young Scientists*' (http://maays.net/). The project team was also unexpectedly awarded '*Best in scientific creativity*' prize (Ng, 2006; Ng, 2008, pp.141-142).

Recommendations for future research

The analysis of students' qualitative feedback on the effects of support tool with coded responses guided by framework analysis (Phillips, 2007) qualitative approach in this study was in fact used as references for refinement of the POSITIVE support tool and to inform further practice in the subsequent studies. During the second phase of study as mentioned above, problem scenarios were created as challenging learning contexts with more scaffolded activities being designed for problem-based learning (PBL). The effects on students' motivation and thinking skills were also evaluated. It is envisaged that at the end of the studies, the POSITIVE support tool could be made accessible for a wider group of participation in technology enhanced PBL with networking opportunities and more proposed solutions to minimize the barriers faced towards Education for All (EFA).

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REFERENCES/ BIBLIOGRAPHY

Asimov, (1990). *The Complete Science Fair Handbook*. Illinois: Good Year Books.

Atwater, M.M. (1994). "Research on Cultural Diversity in the Classroom" in Gabel, G.D. (Ed.) (1994). *Handbook of Research on Science Teaching and Learning: A Project of the National Science Teachers Association*. New York: Macmillan Publishing Company.

Betrus, A. K. (2007). *Individualized instruction-pace, method, content, examples of individualized instruction, final issues*. [Retrieved (6/8/08) from URL: http://education.stateuniversity.com/pages/2085/Individualized-Instruction.html]

Board of Education for the City of York (1989). *Student-centred Learning, Curriculum Resource*. The Board of Education for the City of York.

Borg, W.R., & Gall, M.D. (1989). *Educational research: An introduction*. Fifth edition. NY: Longman Inc.

Cagnole, B., Melograna, S., Morrison, K., Muenchenbach, R., Rees, T., & Waltz, S.(2004). *Ability grouping*. [URL:http://www.users.muohio.edu/shermalw/EDP603SM2004/edp603_groupMelograna.htmlx]

Cohen, R.J., & Swerdlik, M.E. (2002). *Psychological testing and assessment: An introduction to test and measurement*. Fifth edition. McGraw-Hill Higher Education.
Fogarty, R. (1998). *Problem-based Learning: A Collection of Articles*. SkyLight Professional Development.
Gallagher, S.A. & Stepien, W.J. (1996). Content acquisition in problem-based learning: Depth versus breadth in American studies. *Journal for the Education of the Gifted*, v.19, p.257-275
Groves, R. (2009). *Assessment for Learning: Helping Students Learn by Providing Feedback*. Presentation in Joint RECSAM-ICASE Regional Seminar on "The Way Forward for Science and Technology Education: Implications for Policy Makers". 16 to 19 February. RECSAM.
Helgeson, S.L.(1994). "Research on Problem-solving Middle School" in Gabel, G.D. (Ed.) (1994). *Handbook of Research on Science Teaching and Learning*. NY: Macmillan Publishing Co.
Hmelo-Silver, C.E., Duncan, R.G., & Chinn, C.A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist,* 42(2), 99-107. Lawrence Erlbaum Associates, Inc.
Keeves, J.P. (Ed.) (1988). *Educational research, methodology and measurement: An international handbook*. Oxford: Pergamon Press.
Lave, J., & Wenger, E. (Eds.)(1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
Lewin, M. (1979). *Understanding Psychological Research*. New York: John Wiley and Sons, Inc.
McConnell, D. (2000). *Implementing Computer Supported Cooperative Learning (CSCL)*. London: Kogan Page Limited.
McCormick, R., & Paechter, C. (Eds.) (1999). *Learning and Knowledge*. Paul Chapman Publishing Ltd. in association with The Open University.
Ng, K.T. (Ed.) (2002). *Final report on the preparation and implementation of third Regional "Search for SEAMEO Young Scientists" (SSYS) Congress (4-6 March 2002*). RECSAM.
Ng, K.T. (2005). *An evaluation of the scientific creativity and problem-solving behaviours of young learners in the development of investigative project work*. Paper presented in parallel session and published in the Proceeding (*refereed*) for the first International Conference on Science and Mathematics Education (CoSMEd). Conference held from 6 to 8 December at RECSAM. ISSN: 967-930-012-9
Ng, K.T. (Ed.) (2006). *Final report on the preparation and implementation of fifth Regional "Search for SEAMEO Young Scientists" (SSYS) Congress (6-9 March 2006*). RECSAM.
Ng, K.T. (2008). *Evaluative Studies on Problem-Solving Curriculum with Development and Validation of Tools for Cultural Scaffolding in the Management of Project/Problem/Programme-based Learning* (P^3BL). Unpublished doctoral thesis. U.S.: Washington Int. Univ.
Ng, K.T. & Fong, S.F. (2004). Project-based learning via Information and Communication Technology. *Malaysian Journal of Educational Technology (my.JET).* Vol. 4, No. 2, Dec. 04. ISSN: 1675-0292.
Ng, K.T., Tan, K.A. & Toh, L. (2007). Project-based Learning Science Across the World. Published in *digital LEARNING (the monthly publication or magazine on ICT and education*). Volume 3 Issue 2. February 2007. ISSN: 0973-4139. [URL: http://www.digitalLEARNING.in]
Ng, K.T., Sarmiento, C.Q.S., Cheah, U.H. & Wahyudi, Y. (2006). *Promoting ESD via Student-Centred Learning Programme*. Paper presented in the 10th APEID International Conference "Learning Together for Tomorrow: ESD". 6th to 8th December, 2006. Imperial Queen's Park Hotel, Bangkok, Thailand.
Palmer, D. (2007). What is the best way to motivate students in science? *Teaching Science: The Journal of the Australian Science Teachers Association*. Vol.53, No.1, Autumn, 2007.
Pea, R.D. (1995). *Science Education as a Driver of Cyberspace Technology Development*. Illinois: Northwestern University.
Phillips, J.A. (2007). *Education Research Methodology*. UNITEM Sdn. Bh.d
Sill, David J. (2001). Integrative thinking, synthesis and creativity in interdisciplinary studies. *The Journal of General Education*, Volume 50, Number 4, 2001, pp.288-311.
[URL: http://muse.jhu.edu/login?uri=/journals/journal_of_general_education/v050/50.4sill.html]
Simpson, R.D., Koballa, T.R. (Jr.), Oliver, J.S., & Crawley III, F.E. (1994). "Research on the Affective Dimension of Science Learning" in Gabel, G.D. (Ed.) (1994). *Handbook of Research on Science Teaching and Learning.* New York: Macmillan Publishing Company.
Sitkoff, S. (1988). Science centers - An essential support system for teaching science. In P. F. Brandwein & A. H. Passow (Eds.), *Gifted young in science: Potential through performance* (pp. 179-187). Washington, DC: National Science Teachers Association.
[Retrieved (Aug 2008) URL: http://www.nagt.org/files/nagt/jge/abstracts/nowak-v55p62.pdf]
Smith, R.A., & Davis, S.F. (2001). *The psychologist as detective: An introduction to conducting research in psychology*. Second edition. Upper Saddle River, New Jersey: Prentice Hall.
Spavold, Z. (2005). Using Formative Assessment to Raise Pupil Motivation: A Small Classroom-based Study. *School Science Review (SSR)*, 86(317), June. The Association for Science Education (ASE). [Retrieved 1/10/2007 from http://www.washington.edu/students/crscatt/teduc.html].
Szabo, M. (1996). *Interactive Multimedia as Faculty Renewal and Change Agent : A Three-Pronged Approach to Successful Implementation in Malaysia : 'TIE'ing it all Together with Training, Infrastructure and Empowerment*. Presentation in EDUCOMP '96.
Valencia, I.N. (1996). Cognitive and affective factors associated with high school students' motivations to do scientific research. *Journal of Science and Maths Education in Southeast Asia*, Vol.XIX, No.1. RECSAM.
Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, M.A.: Harvard Univ.Press.52-91. [URL: http://www.marxists.org/archive/vygotsky/works/words/lev1.htm]

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