The effectiveness of PBL online on pre-service science teachers’ creativity and critical thinking: a case study at Universiti Malaysia Sabah

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The effectiveness of PBL Online on pre-service teachers’ creativity and critical thinking was the main objective of this study. A cohort of 41 pre-service science teachers from the School of Education and Social Development (SESD) of Universiti Malaysia Sabah, Malaysia comprised the sample. The sample was separated into experimental and control groups, with the experimental group using PBL online learning activities, and the control group more traditional learning activities. The course involved Modern Physics and this course is a compulsory. Both groups were supported via an online learning environment, which acted as the main medium for learning. Participants’ creativity was evaluated using a previously validated instrument, the Torrance Test of Creativity Thinking (TTCT), and their critical thinking was using the Watson Glaser Critical Thinking Appraisal (WGCTA). Both tests administered before (pre-test, Form A) and after (post-test, Form B) the intervention and using two different sets of form. Examination of these data, points to statistically significant differences between the traditional and PBL groups in creativity. However no significant difference was stated in critical thinking. Therefore the research findings suggest that pre-service science teachers’ creativity can be improved by PBL online but more consideration and preparation might be needed in critical thinking aspect.

Key words: problem-based learning; online learning; creativity; critical thinking.

INTRODUCTION

The needs that teachers to be creative is very crucial thus it becomes one of important point to the Malaysian government. One of the nine challenges’ objective as stated in Vision 2020 is that “establishment of a scientific and progressive society that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to the scientific and technology civilization of the future” (Almacen, 2013; Vision 2020, 2011). Innovative and forward-looking is very much related to the creative and creativity. Thus, the creative thinking needs to be moulded from as early as primary stage. This is why it is very important to ensure for teacher to be creative or at least use any other method to teach students that near to the pedagogy to encourage students’ creativity. As noted by Saroja (2008), students’ creative thinking skills can be cultivated effectively if teacher using the right approach (e.g., integrated approach). The President of the Malaysian Association of Creativity & Innovation (MACRI), Datuk Ghazi Sheikh Ramli, claims that the creativity of Malaysians is suppressed by the education system, and a perceived need to follow societal norms. He adds that Malaysian society generally constrain children’s learning, arguing that children need space to grow, and when this space is not given, it kills their natural creativity. This is also reported in other cultures such as in Pacific Island nations (Sade and Coll, 2003; Coll, Ali, Bonato and Rohindra, 2006). Ghazi claims that in more open societies such as Western nations, students are encouraged to challenge the opinions of their lecturers and elders.

Creative thinking and learning science

‘In the Malaysian compulsory education system, education about thinking emphasizes skills such as analysis, teaching students how to understand claims,
teaching them how to follow or create a logical argument, how to figure out the answer, eliminate incorrect ideas, and focus on the ‘correct’ answer. This is a very traditional approach to learning science, one that suggest to students that science is a codified body of factual knowledge; a body of content that must be learned and repeated verbatim upon request (Millar, 1989). Harris (1998), however, suggests there is another kind of thinking we should foster; one that focuses on exploring ideas, generating possibilities, and looking for many right answers rather than seeking the one ‘correct’ answer. We suggest here that both ways of thinking are useful in working life after graduation, yet it seems the latter tends to be ignored until after college in many countries including Malaysia. According to Chua (2004), there are four main steps that we need to take in order to foster creative thinking: remove barriers to creative thinking; make students aware of the nature of the creative process; introduce and practice creative thinking strategies; and foster a creative environment.

In Malaysia, efforts are now being made to encourage creativity through both curricular and co-curricular activities (Utusan Malaysia, 2008; Yong, 1986, 1993). As noted recently by the Deputy Prime Minister of Malaysia, Tan Sri Muhyiddin Yassin (also the Minister of Education), and Malaysian education urgently needs to be transformed if we are to enhance economic development by application of creativity and innovation (Zakaria, 2010). Thus, in Malaysia teachers are encouraged to use pedagogies to promote creativity, and students are likewise encouraged to be innovative and come up with new ideas. Students are encouraged to participate in creative activities, allowing them to become conscious of the ways in which they think and learn.

**Fostering and measuring creative thinking**

Creativity or creativeness is a mental process or mental activity involving the generation of new concepts or theories, or new associations between existing concepts or theory (Cowley, 2005; Harris, 1998). An everyday conceptualization of creativity is that it is simply the act of creating something new (Awang & Ramly, 2008). However, according to Torrance (1984), creativity comprises four elements: fluency, flexibility, originality, and elaboration. Guilford (1964) says creativity involves ‘divergent thinking’, engaging in a process of creating many new and different thoughts about a topic over a short period of time.

It seems creativity is usually measured by means of survey instruments. The main instrument reported in the literature used to measure creative thinking is *Torrance Test of Creative Thinking* (TTCT, Forms A & B) (Torrance, 1990). Torrance (1966, 1990) suggests that creative thinking means to generate new ideas, the student must produce more and more ideas (i.e., be fluent), and include a variety of different ideas (i.e., be flexible), ideas that are unique (i.e., original ideas), and that such ideas need to be specific, detailed and useful (i.e., they are valuable). To measure these skills, the TTCT in Form A (for pre-test) and Form B (for post-test) are used. There are no major differences between the tests since the questions in each form revolve around six activities (Flow-chart 1).

Each answer in this instrument is scored using the following criteria:

(i) Fluency,
(ii) Flexibility,
(iii) Originality, and
(iv) Elaboration.

Juremi (2003) reported good construct and criterion validity, for both versions of the TTCT in the Malaysian context, suggesting they would likely to be suitable for use in the present inquiry. Additionally, work by Ghouse (1996), supports the construct validity of the TTCT who were taught how to think creatively, compared with a group taught traditionally.

**Critical thinking**

Critical thinking skills are considered important by many authors (Brown et al., 2000; Huit, 1998) and most authors argue that students must learn to become more thoughtful about what they learn in order to develop skills in problem-solving. The main purpose for developing critical thinking skills in students is to prepare them to succeed in the future, and thereby improve their quality of life.

Many authors now feel that education must consist of more than an unreasoning accumulation of facts and skills, and to become active participants in a contemporary community requires in students a highly-developed critical awareness to cope with life issues (Huitt, 1998). Most advocates of thinking skills such as critical thinking and creativity highlight the relevance of such thinking skills for everyday living. The argument here is that critical thinking is the art of taking charge of one’s own mind, in which case its value is plain: if we can take charge of our own minds, we can take charge of our own lives. Other authors argue that critical thinking is not an isolated goal unrelated to other important goals in education (Rusbult, 2006).

Rather, it is a seminal goal which, done well, simultaneously facilitates a host of other learning outcomes. Rusbult suggests critical thinking is best visualized as a core of education. To illustrate with an example, as students learn to think more critically, they may become more adept at mathematical, historical and scientific thinking. Critical thinking is not normally presented as an intrinsic part of instruction and students
are not often exposed to explicit instruction in such skills, with teachers tending to take it for granted that critical thinking is automatic by-product of their teaching. However, Rusbult (2006) argues that without critical thinking being systematically designed into instruction, learning is likely ephemeral, and superficial.

Philosophers also have considered the value of critical thinking with authors such as Paul reminding us that critical thinking is a process of thinking to a standard (Paul, 1990). Simply being involved in the process of critical thinking is not enough; it must done well and should guide the establishment of our beliefs and impact on our behaviour or action. Proficient and critical thinking as an important element of life success to the movement of information age is emphasized by Huitt (1995), who claims that critical thinking needs to be a key focus in schooling. Huitt argues that old standards of simply being able to score well on a standardized test of basic skills cannot be the sole means by which we judge the academic success or failure of our students.

Given traditional conceptualizations of the purpose of the education, one might expect that evaluation would focus on higher level thinking such as critical thinking. However, evaluation of general education programs tends to be driven by instrumentation such as national tests, and exams. Research of students’ critical thinking skills is rare (Facione et al., 1995), and there are few multi-institutional and longitudinal studies which include sufficient control of variables and appropriate comparison groups (Ewell, 1993; Pascarella and Terenzini, 1991). Empirical research on critical thinking skills is further inhibited by disagreement among theoreticians with regards to the definition of the construct (Ewell, 1993; Jones and Ratcliff, 1993; Kurfis, 1988). However, recent evaluation of critical thinking skill development suggests that at the college level at least, improvements in critical thinking have occurred (Astin, 1993; Ewell, 1993; Facione, 1990). The next section considers what pedagogies have been helpful in improving critical thinking.

**Pedagogies reported to enhance students’ critical thinking skills**

The literature suggests that higher order thinking skills among students are essential in problem solving, and that critical thinking is an important part of problem-solving (Juremi, 2003). In addition, through explicit teaching of critical thinking, students are exposed to concepts such as inference, deduction, interpretation, judging and argument, all of which encourage them to think critically.

There are many teaching approaches reported to improve critical thinking: project-based online learning (Kurubacak, 2006); dialogic-learning (Frijters et al., 2008); immersion learning (Warren et al., 2004); a collaborative faculty approach (William et al., 2003); problem-solving (Zohar et al., 1994); evidence-based practice (Proffetto-McGrath, 2005); asynchronous discussions (Walker, 2005); problem-solving on the Internet using Web-based authoring tools (Neo and Neo, 2000). For example, Juremi (2003) reports that a PBL approach improved students’ critical thinking by teaching them explicit critical thinking learning process skill (i.e., evaluate all the relevant information and knowledge to solve a particular issue; thus by this phase the application of critical thinking subset will occur, making an inference, making an assumption, deduction, interpretation and also evaluation of argument).

Other research by Zohar et al. (1994) likewise suggests that activities that expose students to use of critical thinking skills such as discussion in class and in a small group, experimental analysis, data management and
problem-solving, are capable of increasing their critical thinking skills.

PROBLEM-BASED LEARNING

Problem-based learning (PBL) is a pedagogical approach to science education that focuses on helping students develop self-directed learning skills (Barrows and Tamblyn, 1980; Boud and Felleti, 1991). PBL has its origins in the Medical School of McMaster University (Rideout and Caprio, 2001; Sulaiman, 2011), but has since been used in a variety of other contexts. It derives from the idea that learning is a process in which the learner actively constructs new knowledge on the basis of current knowledge.

Unlike traditional teaching practices in higher education, where the emphasis is on the transmission of factual knowledge, PBL consists of providing students with a set of problems (Sangestania and Khabitan, 2012) that are carefully sequenced to ensure the students are taken through the curriculum in a measured fashion. The students encounter problem-solving situations in small groups guided by a tutor, who facilitates the learning process by asking questions and monitoring the problem-solving process. The ability to solve problems here is more than just accumulating knowledge and rules; it is the development of flexible, cognitive strategies that help analyze unanticipated, ‘ill-structured’ situations with an end result of producing meaningful solutions. Even though many of today’s complex issues are within reach of student understanding, according to the literature the skills needed to tackle these problems are often missing in our pedagogical approaches (Hitchcock, 2000; Hmelo-Silver and Lin, 2000).

Research points to positive feedback from students engaged in PBL, with a number of self-reported benefits identified: having fun learning; learning from each other; not falling behind as everyone is constantly learning; more effective learning as PBL enables students to remember better; students having to interact; and, real-life problems seen as more interesting and challenging (Dublin Institute of Technology, 2005).

However, PBL is not just about problem solving, and it is important to distinguish between PBL and learning via problem-solving. In physics, the use of learning problem-solving is well established, and in this students are first presented with content, in the form of a lecture, and are then given problems to solve which are typically ‘solved’ via the use of algorithms or comparison with worked examples. These ‘problems’ are typically narrow in focus, test a restricted set of learning outcomes, and usually do not assess other key skills.

This type of drill work is not problem solving in the sense that scientists view problem solving; it is rather learning how to solve numerical problems. When learning in this way, students do not get the opportunity to evaluate their knowledge or understanding, to explore different approaches, or to link their learning with their own needs as learners. They have limited control over the pace or style of learning, and according to the literature this method tends to promote surface learning (Woods, 1994). Surface learners concentrate on rote memorisation (Araz and Sungur, 2007); this often arises from the use of didactic ‘spoon-feeding’, which does not encourage students to adopt a deep approach to learning (Kember, 2000; Kit Fong et al., 2007). Deep learners, in contrast, use their own terminology to attach meaning to new knowledge (Rideout and Caprio, 2001).

In PBL, students determine their learning issues, and develop their own unique approach to solving problems. The members of the group learn to structure their efforts and delegate tasks, and peer teaching and organisational skills are critical components of the process. Students learn to analyse their own and their group members’ learning processes and, unlike problem-solving learning, must engage with the complexity and ambiguities of real life problems. PBL is thus well suited to the development of key skills, such as the ability to work in a group, problem-solving, critiquing, improving personal learning, self-directed learning, and communication.

PBL appears, to at least in part, address concerns about other educational methods noted in the literature, such as how to enhance creative and critical thinking (Ward and Lee, 2002). According to Meier et al. (1996), students taught within a teacher-dominated, lecture-based system are not able to solve problems that require them to make connections and use relationships between concepts and content. Only emerging scientists who are trained and taught to think creatively are likely to be able to solve real life problems. The literature thus suggests if we want our future scientists to be capable of solving some of the problems facing society, then we need to find ways to develop creative thinking skills in our students.

The research reported in this inquiry seeks to investigate the effectiveness of PBL in enhancing students’ creativity skills in Malaysia, and at to see whether or not there is any positive impact on students’ critical thinking.

PBL online

There is now a substantial literature on how PBL and online learning can be combined (see e.g., Candela et al., 2009; Cheaney and Ingebretsen, 2005; Jennings, 2006; Lee2006; Lim, 2005; Savin-Baden and Gibbon, 2006; Savin-Baden and Wilkie, 2006), a combination that is often called PBL online. The argument in favour of this combination is that PBL online is capable of promoting both the development of problem-solving, and students’ ability to use information technology; emphasizing the advantages of PBL as a promoter of process, as opposed to content (Watson, 2002). At first, technology was only used by teachers for administrative purposes, or for
information dissemination (Lim, 2005), but as teachers became more familiar with such technologies, they sought to explore the potential of ICT in delivering collaborative inquiry through online forums (Lim, 2005). Some authors report integrating constructivist-based education of practical work such as PBL with online learning (Lim, 2005).

Integrating PBL with online learning consists of merging the pedagogy (in this case PBL) and delivering the content partly, or entirely, online via the Web. A key feature of PBL online is the online collaboration that occurs as part of the learning activities (Savin-Baden and Wilkie, 2006), and this focuses on team-oriented knowledge-building discourse, and reduced teacher-centred learning (Savin-Baden, 2006). Savin-Baden also note that PBL online involves students working collaboratively in real time, or asynchronously, and collaboration tools such as shared whiteboards, video conferencing, group browsing, e-mail, and forum rooms are important for the effective use of PBL online. Students can learn through the use of Web-based materials such as text, simulations, videos, and demonstrations (Savin-Baden and Gibbon, 2006). In some cases, no print materials are provided, and students only can access materials directly from the course website (see e.g., Yong et al., 2003). In other cases there is a focus on a particular website, through which students are guided by the use of strategy problems, online material and specific links to core material, rather than delivery of PBL solely online (e.g., Savin-Baden and Gibbon, 2006).

In both cases, use of websites is mostly student led/driven, and the materials provided support the learning undertaken in face-to-face PBL groups. An example of such a site is that for the SONIC project (Student Online in Nursing Integrated Curricula) (Savin-Baden and Gibbon, 2006), which used PBL in an interactive environment using FlashPlayer-based physiology resources in order to improve students’ expertise in nursing. Savin-Baden and Gibbon in an investigation of the interrelationship of PBL and interactive media, report that the assessment of PBL combined with interactive media to date has not fully considered the difficulties of combining these two approaches.

There is little in the literature about integrating PBL online and creativity and critical thinking in non-Western settings such as Malaysia. Thus, this study seeks to contribute to the literature by considering how we might foster these two thinking skills amongst pre-service science teachers’ using PBL online for physics.

**METHODOLOGY**

The study was conducted in Semester II during the 2008/2009 academic year at the University Malaysia Sabah (UMS), Malaysia, in Modern Physics course. A cohort of 41 pre-service science teachers from the Science with Education Program from the School of Education and Social Development (SESD) were involved. The student cohorts were separated into experimental and control groups. The experimental group pursued all the PBL learning activities (i.e., collaborative learning, independent learning, self-directed learning, and reflective learning), while the control group were taught in a traditional lecture based learning manner. Both groups were provided with an online learning environment (i.e., using the same learning management system - Moodle). For the PBL group, the students were divided into 4 groups of 4-6 students. Whilst for the traditional group, there were no groups involved, and they studied individually (Figure 1).

The intervention was conducted over 16 weeks. The TTCT and WGCTA instrument was administered one week before classes as a pre-test, and one week after the intervention as a post-test. During the intervention, all the teaching and learning assessment was delivered using the learning management system (LMS) organized by the Educational Technology and Multimedia Unit (ETMU) of the Universiti Malaysia Sabah. The LMS was developed in 2007, and the first author and lead researcher prepared the LMS following PBL and traditional approaches.

For the PBL groups the learning activities started with problems. After they were introduced to the problem, the students had to find their own sources of information in order to develop an appropriate solution. They could find solutions via the Internet, from interviews with their lecturers or tutors, from textbooks, observations, or any method they felt would provide relevant information to help them solve their problems. The students in the PBL group also had to access to the LMS to engage in chat rooms at least once in a week – this was monitored by a facilitator. In these chat rooms they could argue, share thoughts, and start to construct solutions to the problems posed. They also could enter a forum room to post any inquiries or any ideas asynchronously.

Additionally, some linkages, sources and lecture notes were uploaded by the facilitator to ensure the students did not lose their way when trying to find suitable solutions. They were given two weeks to solve each problem, and they had to solve five problems over the semester. In PBL online approach, students separated into 4 groups as it consist of 4 to 6 members. Before they started with the intervention they had been given with a series of daily life situation problems that related to the Modern Physics’s syllabus.

In the first week they distributed the task among group members. Before go on to their further research, they discussed about their hypothesis and prior knowledge about the issues either online or by conventional method. The following task is the individually independent research to find any related information, ideas,
knowledge, or notes to support their explanations about the issue. The following weeks they meet up again via online to discuss, analyse and synthesize their information whether it will be the best solution. If not, they will do the same process in finding the information individually and will come up ones again in a group discussion through online and continue discussing on their matter. The process will continue until the group come up with the best solution for each daily live problem given.

For the traditional group, no major differences were made in terms of their learning activities compared with their usual face-to-face traditional teaching approach. The students in both cohorts were familiar with the LMS, where they already had experience in downloading and reading lecture notes online, accessing tutorial questions and assignments. They were required to submit all answers to tutorial problems and assignments via the LMS, but received no additional learning activities. This use of the LMS, Moodle 2007, followed the suggestion of Jayasundara et al. (2007) that PBL online is easier if it is incorporated into existing learning management systems such as Moodle and Blackboard.

In summary, in this inquiry the intention was to improve pre-service science teachers’ creativity and critical thinking via a PBL online intervention. The data were collected through a creative thinking test - the Torrance Test of Creative Thinking, which as noted above contains four criteria used to evaluate creative thinking. And as for the critical thinking, the data were collected using a critical thinking test – the Watson Glaser Critical Thinking Appraisal. There were five criteria used to evaluate critical thinking in this specific instrument (i.e., inference, assumption, deduction, interpretation and evaluation argument).

Two versions of each thinking test employed, a pre-test (Form A) and post-test (Form B). The purpose of conducting the pre-test was to make sure the students were comparable in term of both thinking skills, and the post-test are intended to see if there were any significant differences after the intervention. The tests were administered in Week 1 and Week 16 of the semester.

Content validity in this administration was checked by a lecturer in the area of creative thinking and critical thinking (at another university form that where the survey administration occurred) who checked the instrument for suitability in evaluating these thinking skills, and an English language teacher checked the instrument for clarity of English language. The instruments for the present study also validated from a pilot study, where a group of students answered the questions and gave feedbacks. This resulted in minor linguistic modifications for clarity.

Creative thinking was evaluated using the four elements that form the basis of the instrument described above; viz., fluency (i.e., students give as many answer as they can), flexibility (i.e., students give as many themes of answers as they can), originality (i.e., students give authentic answers that are different from others), and elaboration (i.e., students give cause and effect for each answer). At the same time critical thinking was evaluated using the five elements that form the basis of the WGCTA
Table 1. Report of Pre-Service Science Teachers’ mean marks for creative thinking pre- and post-test by criterion.

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<tr>
<th>Creative Thinking Criterion</th>
<th>Approach</th>
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<td>Traditional</td>
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<td></td>
<td>PBL</td>
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<td></td>
<td>Pre-Test (N = 21)</td>
<td>Post-Test (N = 21)</td>
<td>Pre-Test (N = 20)</td>
<td>Post-Test (N = 20)</td>
<td>Mann-Whitney U Test</td>
<td>Independent Sample t-Test</td>
<td></td>
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<tr>
<td>Fluency</td>
<td>Mean</td>
<td>26.63</td>
<td>62.19</td>
<td>18.74</td>
<td>66.19</td>
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<td></td>
<td>SD</td>
<td>12.28</td>
<td>22.70</td>
<td>9.59</td>
<td>30.28</td>
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<tr>
<td>Flexibility</td>
<td>Mean</td>
<td>15.74</td>
<td>36.13</td>
<td>13.68</td>
<td>50.06*</td>
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<td></td>
<td>SD</td>
<td>7.23</td>
<td>10.67</td>
<td>7.53</td>
<td>26.57</td>
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<tr>
<td>Originality</td>
<td>Mean</td>
<td>3.16</td>
<td>16.94</td>
<td>2.42</td>
<td>34.13*</td>
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<tr>
<td></td>
<td>SD</td>
<td>3.89</td>
<td>7.92</td>
<td>2.52</td>
<td>20.64</td>
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<tr>
<td>Elaboration</td>
<td>Mean</td>
<td>1.68</td>
<td>10.88</td>
<td>2.21</td>
<td>22.94*</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>SD</td>
<td>2.05</td>
<td>5.20</td>
<td>1.82</td>
<td>15.86</td>
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<tr>
<td>Overall</td>
<td>Mean</td>
<td>37.05</td>
<td>126.13</td>
<td>47.21</td>
<td>173.31*</td>
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<td></td>
<td>SD</td>
<td>19.28</td>
<td>37.37</td>
<td>21.63</td>
<td>85.81</td>
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</table>

Note: *Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-test and Mann-Whitney U test) This was an open-ended test, and so there are no maximum or minimum scores, as occurs with other closed-item instruments.

(i.e., inference; assumption; deduction; evaluation argument; interpretation).

**RESEARCH FINDINGS**

The performance of pre-service science teacher in the Torrance Test of Creative Thinking is provided in Table 1. These data suggest that the students who took part in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better (PBL mean = 173.31, SD = 85.81; traditional mean = 126.13, SD = 37.37 respectively).

The PBL group performed better compared to traditional group where there were statistically significant differences between the groups when the instrument is considered overall for Mann-Whitney U-test analysis (z = -1.65, asym. sig (2-tailed) = 0.04*<0.05) and for Independent Sample t-Test analysis (sig. (2-tailed) t = -2.30, p = 0.03*<0.05) and more detailed analysis of the instrument scales shows some interesting differences between the groups.

There are statistically significant differences between the PBL and traditional groups for three scales, with the PBL group performing better for flexibility, originality and also elaboration (Mann-Whitney U test; z = -2.01, asymp. sig (2-tailed) = 0.04*<0.05; z = -2.65, asymp. sig (2-tailed) = 0.01*<0.05; z = -2.65, asymp. sig (2-tailed) = 0.01*<0.05 correspondingly). The same findings are seen when the data are analyzed with the Independent Sample t-Test where the PBL performed better in flexibility, originality and elaboration significantly (sig. 2-tailed; t=-2.22, p=0.03*<0.05; t=-3.55; p=0.00*<0.05; and t=-3.31, p=0.00*<0.05 respectively).

The performance of pre-service science teachers in the Watson Glaser Critical Thinking Appraisal is shown in Table 2. These data suggest that students who took part
Table 2. Report of Pre-Service science teachers’ mean marks for critical thinking pre- and post-test by criterion.

<table>
<thead>
<tr>
<th>Critical Thinking Criterion</th>
<th>Approach</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Difference in Post-Test</th>
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<td></td>
<td>Traditional (N=21)</td>
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<td>PBL (N=20)</td>
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<td>Mann-Whitney U Test</td>
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<td></td>
<td>Independent Sample t-Test</td>
</tr>
<tr>
<td>Inference</td>
<td>Mean</td>
<td>4.30</td>
<td>5.69</td>
<td>5.11</td>
<td></td>
<td>6.07</td>
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<tr>
<td></td>
<td>SD</td>
<td>2.25</td>
<td>1.44</td>
<td>1.941</td>
<td></td>
<td>1.39</td>
</tr>
<tr>
<td>Assumption</td>
<td>Mean</td>
<td>9.40</td>
<td>10.25</td>
<td>9.26</td>
<td></td>
<td>9.53</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.15</td>
<td>1.94</td>
<td>2.281</td>
<td></td>
<td>2.12</td>
</tr>
<tr>
<td>Deduction</td>
<td>Mean</td>
<td>8.50</td>
<td>9.63</td>
<td>8.68</td>
<td></td>
<td>9.53</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.52</td>
<td>1.51</td>
<td>2.001</td>
<td></td>
<td>1.86</td>
</tr>
<tr>
<td>Interpretation</td>
<td>Mean</td>
<td>9.50</td>
<td>9.44</td>
<td>8.58</td>
<td></td>
<td>9.47</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.98</td>
<td>1.73</td>
<td>1.575</td>
<td></td>
<td>2.20</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Mean</td>
<td>8.10</td>
<td>9.31</td>
<td>7.53</td>
<td></td>
<td>9.40</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.94</td>
<td>1.25</td>
<td>2.695</td>
<td></td>
<td>1.21</td>
</tr>
<tr>
<td>Overall</td>
<td>Mean</td>
<td>40.20</td>
<td>45.41</td>
<td>39.16</td>
<td></td>
<td>44.00</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>10.45</td>
<td>4.61</td>
<td>6.10</td>
<td></td>
<td>4.51</td>
</tr>
</tbody>
</table>

Note: *Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-Test an Mann-Whitney U Test) Maximum mark is 80.

in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better (PBL mean = 44.00, SD = 4.51; traditional mean = 45.41, SD = 4.61), and although the traditional group performed a little better, there were no statistically significant differences between the groups when the instrument was considered overall (Mann-Whitney U test, z =-1.70, asympt. sig (2 tailed) =0.28>0.05; and Independent Sample t-Test, sig. (2-tailed) t=0.99, p=0.33>0.05).

Additionally, more detailed analysis of the instrument scales also shows no statistically significant differences between the PBL and traditional groups for each criterion.

DISCUSSION AND CONCLUSION

The research findings reported in this paper suggest that pre-service science teachers’ creativity as measured by the Torrance Creative Thinking Test (TCTT) was enhanced when they engaged with PBL online compared with their counterparts who were taught more traditionally. The overall means show statistically significant differences students in favour the PBL online group. In particular, it seems that the PBL online pre-service science teachers’ did better for three scales of flexibility, originality and elaboration. This is consistent with the features that are captured in flexibility, originality
and elaboration elements of creative thinking in the Torrance Test.

These findings are similar to work reported by Tan (2000) and Juremi (2003), who say that PBL online increases students’ creative thinking. Tassel-Baska and MacFarlene (2009) also suggest that it is really important to germinate creativity among teachers in order for them to enhance creativity in students by using some constructivists learning approach (e.g., problem-based learning). Furthermore, through online learning, the students in the present work also saw PBL online as a new way of learning, that they felt gave them a number of benefits, and that they felt that the benefits of demonstrated learning effectiveness, justify the extra resourcing, consistent with work by King (2008) where PBL online students reported high satisfaction even with an increased workload.

However, for the critical thinking part the research findings indicate that achievement based on the WGCATA are such that there were no significant differences noted for any criterion of critical thinking. This begs the question as to why none of the criteria shows improvement. There are two main reasons suggested for this. First, the PBL group increases their critical thinking ability by a small amount or second, that the traditional group also increased their critical thinking. To consider these reasons, the educational context at the UMS needs to be examined. The pre-service science teachers were in their second year, and during the intervention this was their fourth semester. At this stage, they were more experienced in how to study at university compared with students who were freshman at that time.

This factor is stressed by Lee et al. (2003) who report that students obtain knowledge based on their adulthood and maturity, as well as their study experiences. This might mean these more ‘canny’ students learn more independently, whether they were in PBL or the traditional group. Another factor that may contribute to this situation is that the pre-service science teacher intake is carefully managed by the Minister and university administration.

Each candidate had to take several qualification tests, and all were interviewed before being accepted as pre-service science teachers, due to the high demand of teaching as a career. For this reason, those in this group actually were selected and arguably more capable students. They are reported to be very hard working (D Gabda, personal communication, September 7, 2010), and will work very hard to make sure they get good marks in their course, including this course on Modern Physics.

This study provides some evidence of the positive effects of using PBL online on pre-service science teachers’ students’ creative thinking. Although some scholars suggest creative thinking is a process involving phases and skills that cannot be learnt in a short time (Chua, 2004) it appears that PBL online has the potential to improve undergraduate pre-service service science teacher.

In conclusion, through PBL online, students were engaged in a holistic form of learning process which was quite different to their traditional experiences. Although at the beginning students were a bit overwhelmed by the workload, the outcomes from this study suggests that PBL online can be useful for pre-service science teachers to nurture creative thinking. This was also agreed by Tassel-Baska and MacFarlane (2009) as it is really crucial for teachers to better understand the creativity first; the flow and the instruction before they practising it in school.

As for the critical thinking, there somehow room for improvement as critical thinking is a bit harder to develop in a very short time compare to creative thinking. Thus this suggests that teachers, curriculum designers and Ministry officials’ should consider the implementation of PBL online at the tertiary level since it seems it may enhanced pre-service science teachers’ creative thinking something local commentators say we need to do if we are to help Malaysia achieve the goals specified in Vision 2020.

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