Research Paper

Problem-Based Learning: Effects on Critical and Creative Thinking Skills in Biology

Jason A. Orozco[1)*], **Rosanelia T. Yangco**[2)]
[1)]*Philippine Normal University,* [2)]*University of the Philippines*

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This study determined the effects of problem-based learning (PBL) on critical and creative thinking skills of second year high school biology students in the Philippines. A quasi-experimental research design using pretest-posttest was employed. One class was exposed to instruction with PBL while the other class was exposed to conventional instruction (Non-PBL). Students exposed to instruction with PBL had higher posttest mean scores in the Critical Thinking Skills Test and Creative Thinking Skills Test than those who were exposed to instruction without PBL. In addition, critical thinking skill appeared to be a significant positive predictor of creative thinking skill. Hence, it is recommended that teachers use the PBL approach in biology classes to enhance the critical and creative thinking skills of the students.

Keywords: biology education, critical and creative thinking skills, problem-based learning

***Author for correspondence:** College of Flexible Learning and e-PNU, Philippine Normal University, Taft Avenue, Manila, Philippines. e-mail: orozco.ja@pnu.edu.ph

INTRODUCTION

What is education in the 21st century? Many educators have been confronted by this question as they endeavor to equip learners with knowledge, skills, and attitude (Soulé and Warrick, 2015). Education experts would agree that education in the 21st century is about honing intelligences (Donovan *et al.,* 2014). As such, educators should embrace innovation and transformation in the teaching and learning processes. They have to make sure that teaching strategies and approaches address the needs of students. Indeed, they are realizing the importance of developing thinking skills (Tan, 2003; Tan, 2009). The role of teachers is indispensable in nurturing thinking skills. It requires enough time and effort to plan, design, execute and evaluate learning activities (Hancer, 2013).

The Constitution of the Philippines encourages all educational institutions to promote critical and creative thinking among Filipinos. The Bureau of Secondary Education endorses the following goals in science: (1) to promote student awareness of the relevance of science to life, and (2) to develop critical and creative thinking skills as well as skills in problem solving (Bureau of Secondary Education, 2009). Many education systems are characterized by learning through memorization, learning by imitation, and learning by modeling (Garcia-Retamero *et al*., 2009; Hamidi *et al.,* 2011; Helikar *et al*., 2015). These systems are important for acquiring fundamental knowledge and skills. However, these are not enough for students to develop necessary thinking skills in order to face real-world problems. Biology teachers have been criticized for giving numerous facts to students and requiring those facts in the examination (Momsen *et al.,* 2010). As a result, the opportunities to stimulate curiosity, inquiry, engagement, and motivation in learning are reduced, if not lost (Tan, 2003).

Critical thinking can be developed through student-centered approach in teaching and learning (Snyder and Wiles, 2015), whereas creative thinking can be enhanced through open-ended questions during class discussion and incorporate problem-based scenarios in student learning activities (Awang and Ramly, 2008) .

Problem-Based Learning (PBL) is a pedagogical approach originally developed for medical schools. A problem acts as the stimulus for students' learning activity. Learning is purposeful as students learn while searching for possible solution to problems and they learn in the context in which knowledge is to be used (Chin and Chia, 2004). PBL promotes higher-order thinking skills, knowledge construction, collaborative learning, and independent learning. Furthermore, PBL helps achieve the purpose of education which is to develop content experts, problem solvers, team players, and life-long learners (Tan, 2009).

Pepper (2009) replaced conventional tutorial and laboratory sessions in three first year course units with problem-based learning in science. The majority of the students indicated that they relished working in groups to share new knowledge, the flexibility in approaches and workload. On the contrary, some students were certain that their learning experience was enhanced but preferred greater direction in the use of PBL.

Akinoğlu and Tandoğan (2007) investigated the effects of PBL active learning in 7th grade science on the students' academic achievement, attitude and concept learning. They concluded that the implementation of PBL had positively affected students' academic achievement and attitude towards science. Moreover, the students' conceptual development significantly improved, keeping misconception at the lowest level.

Chin and Chia (2006) examined PBL for secondary school students using ill-structured problems in biology and proved effective in a case study involving nine students using PBL. They found that several students initially experienced difficulties in identifying a problem by themselves. Eventually, however, they formulated personally meaningful problems for investigation. So it turned out that the ill-structured problems stimulated the students to pose questions which charted their course of action leading to independent inquiry. Students were led to investigate a multidisciplinary element beyond the boundaries of typical school science.

Awang and Ramly (2008) investigated the effect of PBL on the creative thinking skill approach through problem-based learning: pedagogy and practice in the engineering classroom. The findings revealed that the over creativity of the students was characterized by originality and fluency. Students who got high scores on originality showed the ability to produce unexpected ideas while those students who got high scores on fluency showed the capability of producing a large number of ideas in response to problem-solving situations. However, the flexibility scores showed that most of the students were not flexible in their approach in relation to learning and acquiring knowledge.

The study of Yuan *et al.* (2008) on promoting critical thinking through PBL involved 23 baccalaureate nursing students and used quasi-experimental pretest- posttest based on the revised version of California Critical Thinking Skills Test. It was shown that students' critical thinking skills significantly improved in one semester using PBL. Most of the students involved in the study suggested that PBL allowed them to share their opinion with others, analyze situations in different ways and explore the possibilities of solving problems. However, a few of the participants felt very stressed and overloaded during the PBL process.

Edwards and Hammer (2007) pointed out several problems encountered on PBL: 1) Students believed that the tasks were ambiguous; 2) Students experienced difficulties in group work; and 3) Students agreed that individual differences affected the results of their study. On the contrary, the benefits of PBL such as improvement on students' communication skills, ability to locate and evaluate relevant information, and increased capacity for problem solving were also revealed.

The study of Thummarpon and Thongkam (2002) involved 150 participants that were divided into three groups, namely: 1) science-based; 2) art-based and 3) combined group. Twenty-five (25) students per group were randomly assigned to the PBL teaching method and the other 25 were exposed to regular teaching. Findings revealed the following: 1) PBL had a greater effect on academic achievement than the regular teaching method, 2) different group characteristics had no significant effect on academic achievement, 3) teaching methods and characteristics had interaction effects on critical thinking. The results showed that PBL used on science-based students had a greater effect on critical thinking than the regular teaching method.

As a pedagogical approach, PBL has potential in enhancing thinking skills of the students (Chin and Chia, 2004). Although it has been used in other countries, this approach is not widely adopted in the Philippines and not much has been documented on PBL specifically, at the secondary level. Thus, it is conducted to examine if Filipino students' critical and creative thinking skills in biology would be enhanced by PBL.

METHODOLOGY

Sample

Two groups of second year high school biology students, with the age range of 14 to 15 years, in one of the Filipino-Chinese schools in Quezon City, Philippines, were involved in the study. There were 27 students in each group and they were randomly assigned to either the PBL or Non-PBL group.

The Instruments

Two instruments were used in the study, namely, Critical Thinking Skills Test in Biology and Creative Thinking Skills Test in Biology. Both of these instruments were developed by the present researchers from existing test instruments, sent to six experts in the teaching and learning field for review and then revised based on the comments received from the reviewers. These experts includes three science education specialists from the University of the Philippines - National Institute of Science and Mathematics Education Development and three college professors specialize in thinking skills and science education from the University of the Philippines, College of Education. The Critical Thinking Skills Test in Biology is based on the Watson–Glaser Critical Thinking Appraisal (Watson and Glaser, 1991). The test is made up of 39 multiple choice questions each worth one point for a total of 39 points. This test is divided into five-parts: Part I Making inference; Part II Recognition of assumptions; Part III Deduction; Part IV Interpretation; and Part V Evaluation of arguments. The Creative Thinking Skills Test in Biology is based on Torrance Test of Creative Thinking (Torrance, 2006). The test is made up of 13 open-ended questions which require the application of some important abilities in creative thinking skills such as originality, fluency, flexibility and elaboration. This test is divided into seven-parts: Part I Improve a product; Part II Unusual uses; Part III Make another product; Part IV What if; Part V Solve a problem; Part VI Make a story; and Part VII Design an experiment. The students' answers in this test were scored using the scoring rubric for creative thinking skills patterned after the work of Torrance (2006) which is shown in Table 1. <You may email the corresponding author for the copy of these instruments>

Data Collection Procedure

The study covered the first quarter of School Year 2012-2013, which is 40 days, or 8 weeks, long. The lessons included in the study were on ecology. The students had the biology class for one-hour and twenty-minute duration every day from Monday to Friday. The two groups of students participating in the study had different class schedules every morning. The same teacher-researcher executed the two methods of instruction. One group was taught using PBL while the other group was taught using instruction without PBL. Learning activities for the PBL group included short video presentation, group work using non-structured activities and post discussion using software presentation. Those for the Non-PBL group were the same as those of PBL group except for the group work using structured activities (Table 2).

Table 1 Criteria for Scoring Creative Thinking Skills Test Response

Creative Thinking Skills	Criteria	Score
ORIGINALITY	Formulation of ideas that are unique	
	Least original (common idea)	0
	Moderately original (partial/some)	2
	Most original	4
FLUENCY	Number of correct responses	
	No correct response	0
	1-2 correct response/s	2
	3 or more correct responses	4
FLEXIBILITY	Number of acceptable ideas/ products presented	
	No idea/product presented	0
	1-2 product/s presented	2
	3 or more products presented	4
ELABORATION	Completeness of the procedure presented	
	No procedure presented	0
	Almost complete procedure presented	2
	Complete procedure presented	4

Table 2 Lesson Structure for PBL Group and Non-PBL Group

	PBL Group	**Non-PBL Group**
Pre-lecture Activity	Students were asked to watch short video clippings on ecology.	
Motivation	The teacher asked questions based from the short video clipping presented.	
Lesson Proper	Groups were given non structured student activities or problem-based scenarios from which they derived facts, what they need to know, learning issues, possible solutions, new learning issues, and dependable solutions (Lambros, 2004).	Groups were given structured student activities modified from existing workbooks and laboratory manuals. The format of the activity includes the title, materials, introduction, procedure, discussion, summary, and conclusion.
	One representative student for each group shared their output at the end of the activity. Post-discussion followed after the student activity.	
Assessment	Short written quiz about the lesson	

Data Analysis

The data were analyzed using Microsoft Excel and the SPSS 20 for the following analyses: 1) *t*-test for independent samples was applied to the pretest mean scores on the Critical Thinking Skills Test in Biology and Creative Thinking Skills Test in Biology of PBL and Non-PBL groups. It was also utilized to determine if the difference in the posttest mean scores between the PBL group and the Non-PBL group was significant, 2) *t*-test for paired samples was used to determine whether the differences in the pretest and posttest mean scores of the Critical Thinking Skills Test and Creative Thinking Skills Test in Biology between the PBL group and Non-PBL group were significant, and 3) linear regression was used to determine if critical thinking skill predicted creative thinking skill.

RESULTS AND DISCUSSION

The presentation of the results is divided into seven parts: 1) comparison of pretest scores of PBL group and Non-PBL group on Critical Thinking Skills Test in Biology, 2) comparison of pre- and posttest scores of PBL group and Non-PBL group on Critical Thinking Skills Test in Biology, 3) comparison of posttest scores of PBL group and Non-PBL group on Critical Thinking Skills Test in Biology (sub-skills), 4) comparison of pretest scores of PBL group and Non-PBL group on Creative Thinking Skills Test in Biology, 5) comparison of pre and posttest scores of PBL group and Non-PBL group on Creative Thinking Skills Test in Biology, 6) comparison of posttest scores of PBL group and Non-PBL group on Creative Thinking Skills Test in Biology (sub-skills), and 7) critical thinking skill as predictor of creative thinking skill.

Critical Thinking Skills

Prior to the start of the intervention, the pretest mean scores in the Critical Thinking Skills Test in Biology of the PBL and Non-PBL groups were compared using two-tailed *t*-test for independent samples. There was no significant difference (p=0.828) in the pretest mean total score between the PBL group (M=26.07±6.10) and the Non-PBL group (M=25.74±5.09). The results establish that the PBL and Non-PBL groups were initially comparable in terms of critical thinking skills.

To determine if there was an improvement in the critical thinking skills in biology of the PBL and Non-PBL groups, the one-tailed *t*-test for related samples was used. There was a significant difference at the 0.000 level in pretest (M=26.07 ±6.10) and posttest M=31.52±1.87 mean total scores of the PBL group and there was also a significant difference at the 0.000 level in pretest (M=25.74±5.09) and posttest (M=30.04±2.95) mean total scores of the Non-PBL group in the Critical Thinking Skills Test in Biology.

To compare the posttest mean scores in the Critical Thinking Skills Test in Biology of the two groups, one tailed *t*-test for independent samples was used. There was a significant difference at the 0.032 level in the mean total scores of the PBL group (31.52±1.87) and the Non-PBL group (30.04±2.95).

Five Components of Critical Thinking Skills

The five components of critical thinking skills used in the present study were adopted from Watson and Glaser (1991). The five components of critical thinking skills are as follows: Making inference, Recognition of assumptions, Deduction, Interpretation of data, and Evaluation of arguments.

The posttest mean scores of the PBL and Non-PBL groups in the Critical Thinking Skills Test in biology are presented in Table 3.

On the inference skill the posttest mean score has no significant difference between the PBL group (M=5.67±0.88) and Non-PBL group (M= 5.63±1.18) (p>0.05).

On the recognition of assumption skill, the posttest mean score has no significant difference between the PBL group (M= 4.96±0.65) and the Non-PBL group (M= 4.67±0.78).

On the deduction skill, the posttest mean score has no significant difference between the PBL (M= 5.47±0.69) group and the Non-PBL group (M= 5.47±0.69).

On the interpretation skill, the posttest mean score has a significant difference between PBL group (M=7.59±0.93) and the Non-PBL group (M=6.74±1.56).

On the evaluation of argument skill, the posttest mean score has no significant difference between the PBL group (M=7.89±1.42) and the Non-PBL group (M=7.59±1.57).

Table 3 Comparison of the Posttest Mean Scores in Critical Thinking Skills Test in Biology for the Two Groups

Skill	Group*	Mean±SD	*t*-value	Sig.(*p*=)
Inference	PBL	5.67±0.88	0.131	0.100
	Non-PBL	5.63±1.18		
Recognition of Assumptions	PBL	4.96±0.65	1.512	0.137
	Non-PBL	4.67±0.78		
Deduction	PBL	5.47±0.69	0.000	1.000
	Non-PBL	5.47±0.69		
Interpretation	PBL	7.59±0.93	2.438	0.018
	Non-PBL	6.74±1.56		
Evaluation of Arguments	PBL	7.89±1.42	0.725	0.472
	Non-PBL	7.60±1.58		

* N=27 for each group.

Creative Thinking Skills

Prior to the start of the intervention, the pretest mean scores in the Creative Thinking Skills Test in Biology of the PBL and Non-PBL groups were compared using a two-tailed *t*-test for independent samples. There was no significant difference (p=0.899) between the pretest mean total score of the PBL group (M=5.63±4.64) and that of the Non-PBL group (M=5.48±3.87). The results establish that the PBL and Non-PBL groups are initially comparable in terms of creative thinking skills.

To determine if there was an improvement in the creative thinking skills in biology of the PBL and Non-PBL groups, the one-tailed *t*-test for related samples was used. There was a significant difference at the 0.000 level in pretest (M=5.63 ±4.64) and posttest M=18.22±6.91 mean total scores of the PBL group and there was no significant difference at the 0.207 level in pretest (M=5.48±3.87) and posttest (M=6.37±4.23) mean total scores of the Non-PBL group in the Creative Thinking Skills Test in Biology.

To compare the posttest mean scores of the two groups in Creative Thinking Skills Test in Biology, one tailed *t*-test for independent samples was used. The difference between the posttest mean score of the students exposed to PBL (M= 18.22±6.91) and that of the students exposed to Non-PBL (M=6.37±4.23) was a significant at the 0.05 level.

The findings of the present study coincide with those of Tan (2003, 2009) and Awang and Ramly (2008). According to Tan (2009), PBL enhances creative thinking skills. He believes that PBL is a vehicle for cultivating creativity and, therefore, encourages the development of creative thinking skills. This was also validated by the study of Tan (2003) and Awang and Ramly (2008) that PBL has a positive effect on the different aspects or components of creativity.

Four Components of Creative Thinking Skills

The four components of creative thinking skills used in the present study were adopted from Torrance (2006). The four components of creative thinking skills are as follows: Originality, Fluency, Flexibility and Elaboration.

Table 4 shows the mean posttest scores of the PBL and Non-PBL groups in the Creative Thinking Skills Test in Biology.

On the originality skill, the posttest mean score of the students exposed to PBL (M= 6.96±1.95) was higher than that of the students exposed to Non-PBL (M=2.96±2.03). There was a significant difference in the posttest mean scores of the two groups at the 0.05 level. This means that the students in PBL group can produce more unique and unusual ideas in biology. The result confirms the findings of Awang and Ramly (2008) who used Torrance Test of Creative Thinking that the PBL approach significantly improves the student's originality in the creative thinking skills.

Table 4 Comparison of the Posttest Mean Scores in Creative Thinking Skills in Biology for the Two Groups

Skill	Group*	Mean±SD	*t*-value	Sig.(*p*=)
Originality	PBL	6.96±1.95	7.385	0.005
	Non-PBL	2.96±2.03		
Fluency	PBL	9.04±4.13	6.423	0.005
	Non-PBL	3.11±2.44		
Flexibility	PBL	0.90±1.01	3.362	0.001
	Non-PBL	0.15±0.53		
Elaboration	PBL	1.33±1.24	4.561	0.001
	Non-PBL	0.15±0.53		

* N=27 for each group.

On the fluency skill, the posttest mean score of the students exposed to PBL (M=9.04±4.13) was higher than that of the students exposed to Non-PBL (M=3.11±2.44). There was a significant difference at the 0.005 level in the posttest mean scores of the two groups. This implies that students in the PBL group can produce a large number of correct alternative solutions to problem-solving scenarios in biology. The result coincides with the findings of Awang and Ramly (2008) that the PBL approach positively affected the fluency of engineering students.

On the flexibility skills, the PBL group has a higher posttest mean score (M=0.90±1.01) compared to the Non-PBL group (M=0.15±0.53) and the difference in the scores was significant at the 0.001 level. It means that students exposed to PBL approach can generate more ideas from a different point of view in response to problem-solving situations in biology. The result supports the findings of Awang and Ramly (2008) where the PBL approach significantly improved the engineering student's flexibility.

On the elaboration skill, there was a significant difference at the 0.001 level in the posttest scores of the two groups in favor of the PBL group. This means that students exposed to the PBL approach can improve ideas by providing more details in response to problem-solving situations in biology.

Critical Thinking Skill as Predictor of Creative Thinking Skill

Simple linear regression analysis was used to test if critical thinking skill significantly predicted creative thinking skills. The result of linear regression analysis indicated that critical thinking skills accounted for 13.9% of the variation in the creative thinking skills posttest mean score (R^2= 0.139, F(1.53)=8.40) and the regression model was statistically significant (p=0.005). This means that critical thinking skills significantly predicted creative thinking skills. The result of the present study supports the claims of Paul and Elder (2004) that critical and creative thinking are interwoven, inseparable, and interdependent. They argued that "only when we understand critical and creative thought truly and deeply, we recognize them as inseparable, integrated and unitary".

CONCLUSIONS AND RECOMMENDATIONS

The study showed that students exposed to instruction with PBL had higher posttest mean scores in the Critical Thinking Skills Test and Creative Thinking Skills Test in Biology than those who were exposed to instruction without PBL. In addition, critical thinking skill appeared to be is a significant positive predictor of creative thinking skill.

Several studies on PBL revealed that PBL promotes collaborative learning (Pepper, 2009), improves attitude toward science (Akinoğlu and Tandoğan, 2007), develops content knowledge (Chin and Chia, 2004), and enhances thinking skills (Awang and Ramly, 2008; Yuan *et al.,* 2008). In this study, it was indicated that PBL improved test scores of the students in the critical and creative thinking skills tests. Thus, Biology educators should incorporate PBL into the curriculum for the enhancement of thinking skills.

Most of the studies on PBL focused on college students such as in engineering (Awang and Ramly, 2008), nursing (Yuan *et al*., 2008), medicine (Spencer and McNeil, 2009) and education (Semerci, 2006). This study focused on high school students and revealed that PBL was an effective teaching approach in teaching biology at the secondary level. Hence, teachers must use PBL in teaching biology to high school students for the development of students' critical and creative thinking skills.

For further studies, it is recommended: 1) to use PBL in other science subjects such as Physics and Chemistry to see more holistic perspective on the effects of PBL in critical and creative thinking skills, 2) to allot longer time in studying the effects of PBL in other lessons in biology for more thorough results, 3) to increase the sample size of student-participants for more reliable findings, 4) to consider the impact of language or the medium of instructions to generate possible correlation, 5) to identify problems encountered by teachers, students, and researchers to determine hindrances and barriers in the implementation of PBL in secondary education.

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