

# The Effect of Project-Based Learning (PjBL) on Critical Thinking Skills Form Four Students on Dynamic Ecosystem Topic “Vector! Oh! Vector!”

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## Abstract

Project-based learning (PjBL) can effectively help students develop critical thinking skills that are one of the key elements of STEM education. This study aimed to identify the effect of PjBL method on the critical thinking skills Form Four Students on Dynamic Ecosystem topic “Vector! Oh! Vector!” at SMK Zainab, Kota Bharu, Kelantan. This quasi-experimental study was conducted using achievement test that was administered in the form of a pre-post test. The respondents consisted of 60 students that divided into treatment groups (taught using the PjBL method) and the control group (taught using the conventional learning method) for four weeks. Independent t-test was used to answer the research question using Statistical Package for the Social Sciences (SPSS) version 22.0 software. The findings show that there is a significant effect on the construct of students’ critical thinking skills which are the construct that attributing, comparing and contrasting, grouping and classifying, analyzing, detecting bias and evaluating in experimental groups compared to control groups. The findings of this study provide information to school management, District Education Office (PPD), State Education Department (JPN) and Malaysia Ministry of Education (MOE) that the PjBL method can enhance students’ critical thinking skills when used effectively by teachers in STEM education. In conclusion, the implementation of the PjBL method can effectively enhance students’ critical thinking skills which is one of the key elements in STEM education.

## Keywords

Project-Based Learning (PjBL), Critical Thinking Skills, STEM Education

## 1. Introduction

The Ministry of Education of Malaysia (MoE) (2016) stated that STEM education is education based on the concept of educating students in four areas; Science, Technology, Engineering and Mathematics by integrating and applying them in real-world contexts. According to MoE (2012), STEM education is focused on international literacy skills. These skills are creative thinking skills, critical thinking skills, problem solving skills and collaborative learning. STEM education provides a platform for Malaysia to provide a skilled and talented workforce towards sustainable economic development and to meet demand in these areas.

Therefore, it is important that the teaching strategies are well-planned to ensure that the learning goals are met. Various pedagogical approaches have been proposed as the most effective way to engage students in developing a set of thinking skills. These approaches include student-centered learning, active learning, project-based learning (PjBL), and inquiry-based learning (Malaysia Ministry of Education (MOE), 2012). Project-based learning (PjBL) can effectively help students develop critical thinking skills that are one of the key elements of STEM education. Therefore, learning using PjBL is very appropriate to implement in STEM education at school level (Curriculum Development Centre, 2017; Kasim & Che Nidzam Che Ahmad, 2018). Despite various efforts, the implementation of effective teaching strategies in improving students' thinking skills remains a major issue in STEM education. In this regard, studies on the impact of PjBL on students' critical thinking skills should be conducted to ensure that the PjBL method is an effective strategy for enhancing students' critical thinking skills in STEM education.

The previous literature shows that the PjBL method improves motivation in learning and improves problem solving skills (Chiang & Lee, 2016). The PjBL method uses principles of learning through experience (Curriculum Development Centre, 2016) and discovery methods (Hajrić, Sabeta, & Nuic, 2015). The PjBL STEM method is a student-driven, across disciplines, collaborative, and technology-based teaching strategy (Han, Yalvac, Capraro, & Capraro, 2015). The PjBL method is an activity based on inquiry and problem-based learning (Curriculum Development Centre, 2017). Therefore, PjBL is an appropriate learning method in STEM education due to its student-centered learning approach.

The main problem with the PjBL method is that most science teachers express the lack of understanding and lack of exposure to implementing this method into STEM education. Studies by (Ramli & Othman Talib, 2017) suggest that teachers' understanding of implementing STEM is still inadequate. This is due to the lack of information from the responsible parties. There were identified barriers to the study such as motivation, syllabus, time constraints, lack of training, lack of facilities, student engagement and feedback from the school community. (Han, Yalvac, Capraro, & Capraro, 2015) state that teachers' understanding and

implementation of PjBL STEM has a significant impact on content comprehension and student skills development. The role of teachers in implementing PjBL STEM is different from that in the traditional classroom and the development of effective professionalism can help teachers acquire the pedagogical skills needed to implement PjBL STEM. This proves that despite various efforts, the problems in implementing PjBL effectively at school level still cannot be fully resolved.

The findings of this study will be able to identify the effectiveness of PjBL method on the critical thinking skills Form Four Students on Dynamic Ecosystem topic “Vector! Oh! Vector!”. This finding can be used by school management; District Education Office (PPD), State Education Department (JPN) and Malaysia Ministry of Education (MOE) to re-evaluate and improve the implementation of the PjBL method currently being used by science teachers. This is crucial to ensure effective implementation of the PjBL method is able to provide accurate information on students’ critical thinking skills. The effective implementation of PjBL methods can serve as a guide for school management, PPD, JPN and MOE to provide further training to science teachers for the purpose of using PjBL method as it is proven to be effective in STEM education. This is critical because critical thinking skills are crucial to ensuring that a quality workforce in the field of STEM can generate and drive the nation’s economy.

## **2. Project-Based Learning (PjBL) Approach**

According to the (Curriculum Development Centre, 2016), projects are activities that require students to identify ways to solve problems and subsequently plan the entire project. The results of the project in the form of reports, artifacts or other items should be presented. Project-based learning (PjBL) in this study comprises three phases, as a guideline for teachers to carry put STEM teaching and learning (T & L), referring to the use of the BSTEM Biology Module published by (Curriculum Development Centre, 2017). These three phases detail out the steps that teachers need to carry out during the planning and administering in order to achieve an effectively T & L sessions. These three phases require students to think critically, cross-discipline, collaboratively and with the use of technology in solving activities based on inquiry and problem-based learning approaches. The principles derived behind the PjBL approach were according to cognitivism, constructivism and constructionism theory.

### **2.1. Cognitivism and Constructivism Theory**

The main driver of Cognitivism is Jean Piaget. Piaget describes students as knowledge builders. They build their own knowledge by actively shaping and restructuring their knowledge through their own learning experiences. Constructivism is a philosophy of learning that suggests that students need to build their own understanding of new ideas (Açıslı, Yalçın, & Turgut, 2011). Drawing on this view

of cognitivism, there is a view on how humans learn, which is constructive. According to constructivism, knowledge is actively built by students' thinking. Constructive approaches support the fact that individuals build new knowledge based on existing knowledge and play an active role in this process (Yadigaroglu & Demircioglu, 2012).

The (Curriculum Development Centre, 2016) states that constructivism is a belief that students learn something by building their own understanding of themselves. It derives from the idea that knowledge is not something fixed and stable, but rather it is constructed step by step, and it is frequently changed, as individuals and groups continually try to make sense of the complex world around them. Some of the key elements in the constructivism are that teachers take into account students' existing knowledge, learning is the result of their own efforts, learning occurs when students connect original ideas with new ideas to restructure their ideas and students have the opportunity to collaborate, share ideas and experiences and reflect on their own learning.

## **2.2. Constructionism Theory**

Papert argued that Theory of Constructionism is the construction of knowledge through the involvement of students in the construction of shareable artifacts. This theory emphasizes the importance of the role of external objects in the learning process and emphasizes the role of computers in the process of constructing artifacts and appreciating diversity among students. This theory focuses on the social aspects of learning (Ackermann, 2001) and on the building of new ideas that occur best through constructing real-world artefacts (Lay & Osman, 2017).

## **2.3. Combination of Constructivism and Constructionism Theory**

The PjBL approach is based on a combination of Constructivism Theory of Learning by Piaget's Cognitive Development Theory and Papert's Theory of Constructionism. The combination of these two theories states that students are developing new knowledge (Açışlı, Yalçın, & Turgut, 2011), students are actively engaged in learning sessions (Yadigaroglu & Demircioglu, 2012), cooperative and collaborative learning (Krajcik & Czerniak, 2014), learning stimulating student's thinking skills (Chiang & Lee, 2016) and learning through discovery (Malaysia Ministry of Education (MOE), 2016). Therefore, this study is based on a combination of Piaget's Cognitive Learning Theory and Constructionism Theory by Papert, requires that students learn through the process of learning and facilitating phase to enable students to develop new knowledge, engage actively, cooperative, collaborative and discovery learning.

## **3. Students Critical Thinking Skills**

Curriculum Development Division, Malaysia Ministry of Education (Curriculum Development Centre, Malaysia Ministry of Education, 2014) states that

thinking is a mental process that requires the individual to integrate his/her knowledge, skills and attitudes in order to understand and making sense of his or her environment. Thinking skills are formed when students are actively involved in the teaching and learning process. In this process, carefully planned teaching and learning activities can capture the minds of students and encourage them to think so that they can conceptualize, solve problems and making decisions.

(Hasnida, Che Md Ghazali, Siti Rahayah Ariffin, Nor Azaheen Abdul Hamid, & Roseni Ariffin, 2010)'s state that critical thinking skills are a logical, sane, and reflective process of thinking that focuses on the action that needs to be taken whether to accept or do something. (Özyurt, 2015)'s states that problem solving can be considered a product of critical thinking. Therefore, in this study, the effect of critical thinking skills measured by students by answering pre and post-test questions based on nine particular constructs in problem-solving questions as listed (Table 1).

The findings of the study by (Hsu & Shiue, 2018) show that students' cognitive existence is positively influenced by learning and social context, supported by an inquiry cognitive theory framework within the context of the PjBL discipline. This finding indicates that the PjBL method has a positive effect on students' cognitive thinking skills.

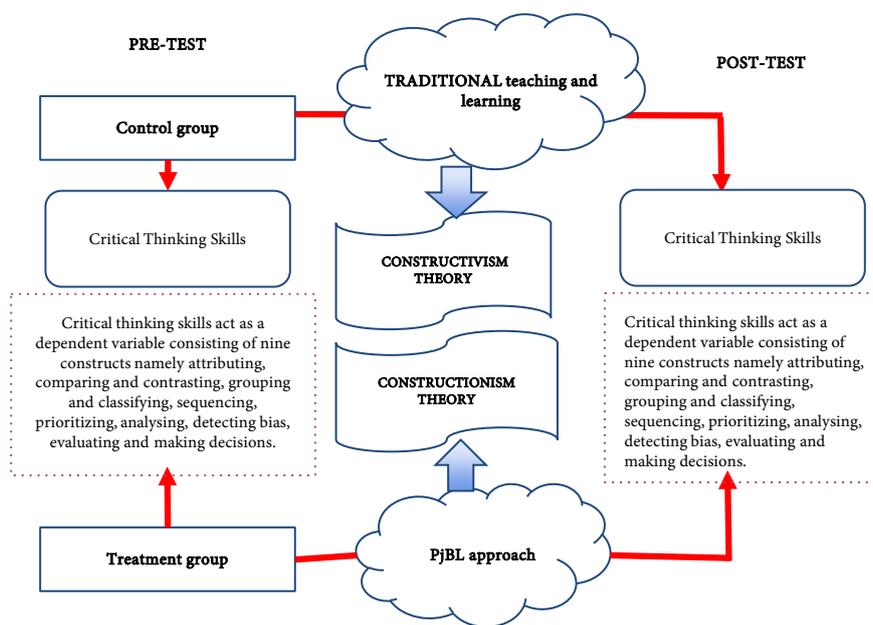
#### 4. Research Methods

The conceptual framework of the study is shown in Figure 1. The treatment

**Table 1.** Critical thinking skills measured in this study.

Particular	Characteristic
a. Attributing	Identifying characteristics, features, qualities and elements of a concept or an object.
b. Comparing and contrasting	Finding similarities and differences based on criteria such as characteristics, features, qualities and elements of a concept or event.
c. Grouping and classifying	Separating objects or phenomena into categories based on certain criteria such as common characteristics or features.
d. Sequencing	Arranging objects and information in order based on the quality or quantity of common characteristics or features such as size, time, shape or number.
e. Prioritising	Arranging objects and information in order based on their importance or priority.
f. Analysing	Examining information in detail by breaking it down into smaller parts to find implicit meanings and relationships.
g. Detecting bias	Identifying views or opinions that have the tendency to support or oppose something in an unfair or misleading way.
h. Evaluating	Making a statement about the outcome of an investigation that is based on a hypothesis.
i. Making conclusions	Making a statement about the outcome of an investigation that is based on a hypothesis.

Source: Curriculum Development Division (Curriculum Development Centre, Malaysia Ministry of Education, 2014).



**Figure 1.** Conceptual framework in this study. Source: Adaptation from Curriculum Development Division (Curriculum Development Centre, 2017).

group used the PjBL method and the control group used the conventional teaching method. Critical thinking skills act as a dependent variable consisting of nine constructs namely attributing, comparing and contrasting, grouping and classifying, sequencing, prioritising, analysing, detecting bias, evaluating and making decisions.

Population of the study consisted of 112 Form 4 students taking Biology at SMK Zainab, Kota Bharu. SMK Zainab, Kota Bharu was selected as the sample of the study based on the its location near Kota Bharu. A total of 60 students were selected as a sample of the study, of which 30 were as control group and 30 as treatment group. Researcher chose SMK Zainab because of their high achiever student, many students taking Biology subjects in this school which support the literature that female students prefer Biology subjects than male students (Isa & Mai Shihah Abdullah, 2017).

Accordingly, in collaboration with a Biology teacher at SMK Zainab, the researcher distribute the pre-test questions to the respondents. The PjBL method were applied to the experimental group and the control group were taught using conventional method for four weeks. After four weeks, post-test questions were administered on the students to find out the effect of PjBL and conventional methods on students' critical thinking skills.

Purposive sampling method was used in the study. According to (Etikan, Musa, & Alkassim, 2016), purposive sampling is useful when researchers have limited resources, time and labor. In order to answer the research question, a set of achievement test questions was developed as a revised research instrument from the (Curriculum Development Centre, 2017) and the Terengganu State SPM Biology Trial question 2015. This test question is divided into two sections,

Part A and B. Part A is demographic of the respondents and Part B consists of nine items aimed at assessing students' critical thinking skills. Both sections A and B were evaluated based on the subjective correct answers of students with a breakdown of the scores by question totaling 40 marks. The test questions were distributed manually to the sample of study. Analysis of data was performed using Statistical Package for Social Sciences (SPSS) software version 22.0. Descriptive analysis was used to analyze data obtained from Part A (demographics) and independent sample t-test analysis was used to answer study question.

## 5. Findings and Discussions

RQ: Is there any significant difference between experimental and control group for achievement post-test score of critical thinking skills students?

An independent-samples t-tests was conducted to evaluate the impact of the interventions on students' scores in the achievement test of students on Dynamic Ecosystem topic "Vector! Oh! Vector!". **Table 2** shows the descriptive statistics and results of the independent-samples t-test for achievement post-test for the nine constructs in the critical thinking skills.

The study found that there was a significant effect of the independent samples

**Table 2.** Critical thinking skills measured in this study.

Critical thinking skills	Group	Mean	SD	t	df	Sig.
Attributing	Treatment	2.35	0.23	-3.48	58.00	0.00*
	Control	2.12	0.28			
Comparing and contrasting	Treatment	2.40	0.67	-5.78	58.00	0.00*
	Control	1.47	0.57			
Grouping and classifying	Treatment	3.13	0.41	-5.27	58.00	0.00*
	Control	2.43	0.60			
Sequencing	Treatment	4.60	0.93	-0.07	58.00	0.95
	Control	4.58	0.98			
Prioritising	Treatment	3.50	0.51	-1.58	58.00	0.12
	Control	3.27	0.63			
Analysing	Treatment	4.50	0.56	-4.18	58.00	0.00*
	Control	3.85	0.65			
Detecting bias	Treatment	4.33	0.88	-3.70	58.00	0.00*
	Control	3.50	0.86			
Evaluating	Treatment	4.33	0.88	-3.70	58.00	0.00*
	Control	3.50	0.86			
Making decisions	Treatment	3.27	0.64	-0.17	58.00	0.87
	Control	3.23	0.90			

Indicator: SD = standard deviation df = Degree of freedom \*significant at  $\alpha = 0.05$ .

t-test for achievement post-test in the experimental group compared to the control group on the six constructs of critical thinking skills namely attributing, comparing and contrasting, grouping and classifying, analysing, detecting bias and evaluating ( $p < 0.05$ ). This finding indicates that the use of PjBL method in the experimental group allows students to develop critical thinking skills in the six constructs stated because with the PjBL method, students are exposed to environmental issues for them to solve by producing an environmentally friendly product. Students also apply their knowledge of pathogen control, apply environmental value and design products for universal good (Curriculum Development Centre, 2017). This is supported by the findings of (Karim & Zanaton Iksan, 2017) who found that the PjBL method can help students solve problems in addressing the issue of product development as a learning artifact. Through the artifacts produced, students are able to work through problems, making decisions, create and do research.

However, there was no significant effect of PjBL post-test scores on the construct of sequencing, sorting priorities and making decisions in the experimental group compared with the control group. This indicates that students in the control group taught using the conventional method were able to match the pupils in the experimental group taught using the PjBL method in three critical thinking skills constructs mentioned. The findings of this study are in line with (Isa & Mai Shihah Abdullah, 2017)'s which stated that teacher-centered conventional methods are still relevant to teaching and learning sessions on the topic, although students in the control group did not go through the process of seeking information, presenting processes and producing prototypes in teaching and learning sessions. The teacher can facilitate the learning in the form of support and motivation that may help the students to cope with the challenge in accomplished their goals of projects (Halim, Soh, & Arsad, 2018).

Overall, this finding illustrates the PjBL method used in the topic of Dynamic Ecosystem "Vector! Oh! Vector!" is effective in improving six constructs of student critical thinking skills. This finding supports the study by (Rasul, Lilia Halim, & Zanaton Iksan, 2016), (Shahali, Lilia Halim, Mohamad Sattar Rasul, Kamisah Osman, & Mohd Afendi Zulkifeli, 2017) who found that the level of 21<sup>st</sup> century skills pupils increased significantly especially in the element of inventive thinking through small group activities because students needed to think together how to solve the problems they are facing using their own experiences. Hence, the PjBL method requires students to take responsibility for their decisions and their own learning (Ruddell, 2000).

## 6. Implications of the Study

This study has successfully identified significant effects of PjBL post-test scores on six constructs of critical thinking students in the experimental group compared to the control group. As such, it is imperative for science teachers to emphasize and expose students to real (authentic) questions and to find meaning in

issues that need to be resolved through designing prototype product.

This finding can be used by school management, district office, state department and ministry of education to improve the training system and exposure to science teachers on the implementation of PjBL methods in STEM education, as suggested by (Ramli & Othman Talib, 2017). This is important to ensure that students who are taught the PjBL method in STEM education have high critical thinking skills in order to meet the ever-increasing demands of the workforce.

These findings enable school management and the respected bodies to think of appropriate initiatives to continue to provide awareness to science teachers on the benefits of PjBL methods in STEM education. In addition, there is still room for school management, district office, state department and ministry of education to further enhance training and exposure on effective PjBL implementation. These include improving the motivation, support, preparation and coordination of a robust curriculum so that science teachers can effectively implement the PjBL method. Such an approach will surely make science teachers work at least once every six months to implement the PjBL method in STEM education that will directly enhance students' critical thinking skills.

The findings of this study also add value to the student-centered learning strategy, the PjBL method in teaching and learning sessions using the BSTEM Biology module published by (Curriculum Development Centre, 2017). The findings of this study prove that BSTEM Modules are specifically designed to implement the PjBL method according to three main phases, before teaching and learning (T & L), during T & L and after T & L as an effective guide in enhancing six student critical thinking skills constructs in the topic of Dynamic Ecosystems "Vector! Oh! Vector!".

## 7. Conclusion

Critical thinking skills are extremely important for students to master in the face of increasingly challenging work in science and technology. Conventional teaching methods are seen as less capable of effectively developing students' critical thinking skills. Therefore, it is important for science teachers to have sufficient understanding and training to implement the PjBL method in STEM education as the PjBL method has proven to enhance students' critical thinking skills. While there are many obstacles and challenges in ensuring that science teachers implement the PjBL method effectively, school management, District Education Office (PPD), State Education Department (JPN) and Malaysia Ministry of Education (MOE) should take appropriate action in addressing this so that students who are taught using the PjBL method will benefit in particular in their critical thinking skills.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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