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INTEGRATED STEM PROBLEM-BASED LEARNING APPROACH: A STUDY ON MALAYSIAN UNDERGRADUATES' ACHIEVEMENT IN LEARNING GENETICS CONCEPTS

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Abstract:

Science, Technology, Engineering, and Mathematics (STEM) education should focus on producing scientific and innovative society as emphasized in the Malaysia Education Blueprint for Higher Education (2015-2025). The blueprint states STEM education to be practised at higher education institutions to produce competent graduates. This study echoed the initiatives of implementing STEM at higher education institutions. Hence, STEM education module integrated with Problem Based Learning (PBL) approach was developed. PBL approach was chosen as means to deliver STEM education because PBL approach fosters teamwork and engagement in learning. The Integrated STEM-PBL module was used to measure the achievement towards genetic concepts. A pre-experimental research design with one group-posttest design was applied. A total of 50 participants who are first-year undergraduates from the faculty of biology from a public university in Malaysia were studied. Genetics Concepts Achievement Test (GCAT) was used to measure the achievement towards genetics concepts in this study. The GCAT was validated by experts with Kuder-Richardson 20 (KR-20) internal consistency reliability measure. The administration of GCAT at pretest and posttest showed that the integrated STEM-PBL module enhanced and retained the students' achievement in genetics concepts

Keywords:

STEM, Problem Based Learning, Achievement, Undergraduate, Malaysia

Introduction

STEM professionals are fuel for STEM related jobs and boost the national economic growth (National Academics of Science, Engineering, and Medicine, 2018). This made possible if STEM education is integrated into higher education institutions to prepare the undergraduates for STEM professions (Akiri & Dori, 2022). Thus, this study introduces integrated STEM-PBL approach to the undergraduates at higher education institution because PBL focus on student-centred learning. This is aligned with the Malaysian Qualifications Agency to move from teacher-centred towards student-centred in teaching and learning (Lam, 2011).

On the other hand, STEM education in Malaysia has also undergone changes to keep up with the current needs in education. Changes are in term of curriculum coverage, means of contents delivery and teaching approaches. This is for keeping up with the globalization, new demands, trends and addressing local and global issues.

Malaysia Education Blueprint for Higher Education (2015-2025) highlighted that STEM education at higher education institution is aimed for preparing the graduates for STEM related job. Preparing the STEM graduates is an urgent assignment for the higher education institutions for the country's future (Geesa et al., 2022). Thus, it is important to nurture STEM undergraduates and improve their learning performance. Improving students' scores for STEM subjects in each semester examination is an indication of improved STEM achievement. This study is focused on enhancing students' achievement in genetics concepts by focusing on the first-year undergraduates.

Integrating PBL into the teaching and learning enable success in STEM achievement. PBL approach will guide students towards a better understanding of STEM. PBL encourage hands-on activities in projects and assignments completion is a good means for the undergraduates to experience an engaging learning (Huang et al., 2022). In this study, the first-year undergraduates are exposed to learn by relating the real-world problems experiences and working together with course mates to find a solution to the given problem. Introducing PBL approach in learning STEM will encourage students to become a self-direct learner (Fadhilah et al., 2022). Hence promoting self-discoveries and learning to solve problems, in the end turns the undergraduates into STEM competent human resources upon completion of their university's studies.

Moreover, PBL integrates learning and the real-world applications (Hmelo-Silver 2004; Salomon & Perkins, 1989). PBL activities are carefully designed to nurture undergraduates' interest in learning genetics. There are few characteristics of good PBL activities as suggested by Duch, Groh, and Allen (2001), such as, (i) the problem must motivate students to seek out a deeper understanding of concepts in the subject they want to learn, (ii) the problem should require students to make reasoned decisions and to defend them in correct way, (iii) the problem should incorporate the content objectives in such a way as to connect it to previous courses or knowledge they had, (iv) if used for a group project, the problem needs a level of complexity to ensure that the students must work together to solve it and, (v) if used for a multistage project, the initial steps of the problem should be open-ended and engaging to draw students into the problem.

Genetics subject and STEM

Genetics subject lies at the centre of biology because the same basic genetics principles applied in other biology related fields, such as, to microbes, plants, animals and humans. Genetics underpins many exciting areas of science such as biomedical science, biotechnology, conservation biology and forensics. According to Redfield (2012), genetics is not only learnt in class, but genetics has also become highly relevant to students' lives with news stories nearly every day about its impacts on health and society. Literature shows that both teachers and students experience difficulties to teach and learn genetics respectively (Ittah & Yarden, 2021; Cebesoy & Oztekin, 2018; Agboghoroma & Oyovwi, 2015; Cimer, 2012). This is due to the abstract nature of genetics because its processes are cellular. Chu and Reid (2012) stated that genetics is multidisciplinary involving mathematics and its application in engineering. An integrated STEM approach that is interdisciplinary could provide an efficient way to learn genetic (Ittah & Yarden, 2021). This is mainly because an integrated STEM approach offers more hands-on activities. Mandusic and Blaskovic (2015) and Monvises, Ruenwongsa, Panijpan, and Sriwattanarothai (2011) reported that learner centred activities will turns abstract genetic processes concrete and improves learners' academic performance in genetics.

The elements in STEM, which are the Science, Technology, Engineering, and Mathematics play its own roles to contribute to meaningful activities (Fadhilah et al., 2022). For science, scientific inquiry including predicting and measuring the effect of variables on the final solution for the activity is given priority. Careful observation, measurement, and recording are done (Huang et al., 2022). The elements of science which are needed in the genetics related activities, are the (i) understanding of the basic principles and functions of genetics concepts for each given problem scenarios, (ii) scientific investigation, (iii) science as inquiry, (iv) identifying questions to be answered in each problem scenarios, (v) designing and conducting investigations to solve genetic problems, (vi) using tools to gather and interpret data, and (vii) developing and understanding of genetics concepts. In the activity of the module, at the Stage 3, which is the Idea Generation Stage, it requires the students to brainstorm some solutions to the problem that they have researched and they need to explores the various factors of the given problem. They are required to list out at least three possible idea that facilitate them to solve the given problem.

In this study, for the context of STEM-PBL approach, technology is considered as a solution towards a problem and not creating a product. Thus, the elements of technology that are studied in this study are the (i) understanding of attribute designs, (ii) developing the ability to apply design processes to solve the given genetics problems, (iii) identifying appropriate problems in each problem scenarios, (iv) designing solutions for each genetics problem scenarios, (v) revision before making improvements, (vi) evaluating solution for given each genetics related problems, (vii) controlling and timing actions, and (viii) reasoning with evidence for every genetics scenario. In the activity of the module, at the Stage 4, which is the Learning Issues Stage, students need to design the solutions to solve the given genetics related problems. For this, they have to identify the learning issues as much as they could. The more learning issues that are generated, it gives more ideas for them in order to get more information which might be helpful for them to solve the given problem. Students need to list all the learning issues arise via the group discussion. Since this is a group work thus they need to works in a group to solve the given problem.

In the context of STEM, engineering is not about teaching engineering knowledge, but it is about teaching engineering thinking (Asfaw et al., 2022). Elements of engineering that attributed in the context of STEM are the (i) define the genetics problem in each problem scenarios, (ii) generate genetics concepts in each problem scenarios, (iii) develop a solution in each problem scenarios, (iv) construct and test a prototype in each problem scenarios, (v) evaluate the solution for given genetic scenarios, and (vi) present the solution for those genetics related scenarios. In the activity of the module, at the Stage 5, which is the Self-Directed Learning, the students need to search information regarding the learning issues via group discussion. They are given the opportunity to choose the learning issues that they want. Before ends the session, tutor inquires into possible research source that they will look into. Students need to present the information regarding the learning issues by following week. They are given enough time to search information related to the given work. To summarize, in these stages (Stage 3 to 5), the group generates possible ideas, explanations or hypotheses to understand or solve the problem. Then, group determines what needs to be learnt in order to solve or explain the problem. The group then seeks, selects and summarises relevant information.

For Mathematics, it uses math to test the solution for given each genetics problem scenarios. Elements of mathematics that showed in the context of STEM are the (i) understanding ways of representing numbers, (ii) selecting appropriate methods for estimating and measuring, and (iii) collecting and handling data. A number of questions throughout the activities in the module requires the students to use the genetics mathematical calculation to solve and conclude the scenarios accordingly.

Methodology

Research design of this study is pre-experimental. A pre-experimental research design is one group pretest-posttest design (Cohen, Manion, & Morrison, 2007). This design involves the use of an intervention on a target population that lack the element of random assignment and makes use of intact classes. This method is chosen because it is quite possible for the researcher to study educational related problems when the participants already present in a situation or in intact group (Creswell, 2005). It is usually used and termed effective because they make use of pre-post testing and have independent variables which already exist (Morgan & Morgan, 2001). The use of symbols for pre-experimental design in this study are as suggested by Campbell and Stanley (1963) as shown in Figure 1.

R	**O_1**	**X**	**O_2**	**O_3**
Indicators:				
O_1	Pretest			
X	Intervention			
O_2	Posttest			
O_3	Delayed Posttest			

Figure 1: One Group Pretest-Posttests Design

This study measures the dependent variables in (O_1) where the interest and achievement towards genetics concepts and critical thinking skills among the samples of the study in pretest. After the pretest, this same group will receive intervention (X) on STEM through PBL for eight weeks. After intervention completed, the researchers measured the same variables of the study in the posttest (O_2). Then, the mean scores differences between pretest and posttest ($O_2 - O_1$)

were calculated. Delayed posttest (O_3) is carried out after six weeks from posttest (O_2). The mean score differences between O_3 and O_2 ($O_3 - O_2$) will show the retention on dependent variables after the implementation of intervention. The data collection of the research will take around 16 weeks to complete, pretest will be carried out before the intervention begins, (b) intervention was employed for 8 weeks, (c) posttest will be carried out one week after the intervention ended, and finally, before analyzing data, delayed posttest will be carried out 6 weeks after the intervention ended.

Sample of Study

This study aimed at all undergraduates who registered for genetics course in second semester of academic year 2017-2018 in one of public universities in Malaysia. However, according to Fraenkel and Wallen (2006), the target population by the researcher to carry out the research and to serve as a basic generalization to the study but is very difficult to get all of them to participate due to few factors. But, according to Noraini Idris (2010) stated that researcher can only get population that are more realistic choices.

After completing their first degree, these undergraduates might further their study to postgraduate level or get a job in a variety of environments, which requires them to have knowledge in Science, Technology, Engineering and Mathematics. The participants are considered homogeneous with respect to their previous knowledge and experience in the learning process of instructional planning. The samples were selected from an intact group and it is assumed that the ability of the first-year undergraduates were equivalent. The benefits for participating in the study have been explained to participants before conducting the study. Undergraduates were grouped into 10 groups and per group there are five group members. Each of them plays different roles in the group. The lecturer randomly assigned the group members to control the participant variable. There are no control group in this study.

Samples to participate in the intervention were selected through purposive sampling techniques or known as non-random sampling. Random sampling cannot be done because the sample selection requires the involvement of management from the respected biology faculty and the availability and readiness of genetics lecturer and undergraduates to participate in the study. Therefore, the sample of this study are from existing group in the selected university. There are no criteria in determining the location of the university (different regions in Malaysia). The selected university is based on the willingness and cooperation that the faculty's gives after briefing regarding the study to the Biology Faculty's Dean and Chairperson of Biotechnology program in the respected university.

This samples size is 50 from first-year undergraduates from Faculty of Biology in one of well-known public university in Malaysia, who take genetics course in second semester of academic year 2017-2018. The undergraduates were given the consent form, so that they really understand the rules before participating in this study. This is to make sure; they are fully prepared and know what is expected from them. This will also make the data collection process occurs in natural environment and as per plan by the researcher.

Face and Content Validity

The researcher conducts face validity and content validity for instruments of GCAT which was developed Smith, Wood, and Knight (2008). Validity of this instrument is done prior to a pilot study. GCAT was validated by three experts, which are the, i) biotechnology lecturer for first-

year undergraduates' course with 16 years teaching and research experiences, (ii) science lecturer in research field and teaching genetics related course with 8 years of experiences, and (iii) science lecturer in research field and teaching genetics related course with 10 years of experiences. These experts validated the GCAT through face validity and content validity. S-CVI/average value for GAT is 0.93. Comments from the experts were taken full consideration to ensure the instruments to measure the genetics interest level among the undergraduates.

Reliability of GCAT

To determine the reliability of Genetics Achievement Test and its time management for answering, a pilot test was conducted on 30 respondents. The Kuder Richardson Formula (KR-20) reliability measure was 0.732 on GCAT. In this case, this statistic falls within the acceptable ranges (Haber, 1998). After the pilot test, several respondents were selected randomly and interviewed. The informal interview done to obtain constructive feedbacks from the respondents to improve this instrument. After improvements were made based on feedback from these respondents' point of view; this instrument has been sent to same experts for conclusion before administrating into main study.

Data Analysis

Table 1 shows the descriptive analysis for the dependent variables, the achievement towards genetics concepts. Based on the analysis results, it was found that the mean score of posttests is recorded as (M=7.82, S.D.=2.66) were relatively higher than the mean score of pretests (M=5.90, S.D.=2.19). Similarly, the mean score of the delayed posttest recorded as (M=8.84, S.D.=2.63) was slightly higher than the mean score of the posttest (M=7.82, S.D.=2.66) for achievement towards genetics concepts.

Table 1: Description on Mean, Standard Deviation, Minimum and Maximum Value for Achievement

	Pretest	Posttest	Delayed Posttest
N	50	50	50
Mean	5.90	7.82	8.84
Standard Deviation	2.19	2.66	2.63
Minimum	2.00	1.00	2.00
Maximum	11.00	13.00	14.00

Multivariate test results as in Table 2 shows the main effects of test periods on achievement towards genetics concepts are significant (Wilks' Lambda = 0.252, F (2, 50) = 71.30, p<0.05, partial eta squared, η_p^2 = 0.748). Based on Cohen (1988), the partial eta squared, η_p^2 = 0.748 obtained in this study indicates that the size of the test time effect on achievement towards genetics concepts is large.

Table 2: Multivariate Test Results on Mean Score for Achievement

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Achievement	Wilks' Lambda	0.252	71.30	2.000	48.000	0.000	0.748

Multivariate test output can be supported with univariate test findings for within subject's variable. The assumptions of sphericity will be checked using Mauchly's Test of Sphericity before selecting appropriate univariate test.

Table 3: Result of Mauchly's Test of Sphericity for Achievement

Within Subjects Effect	Mauchly's W	Approx.Chi-Square	df	Sig.	Epsilon[b] Greenhouse Geisser / Huynh-Feldt
Achievement	0.719	15.829	2	0.000	0.781/0.802

Mauchly's test of sphericity in Table 3 showed that this assumption was not met, $\chi^2 (2) = 15.829$, p=0.000 (p<0.05), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (0.781). If data violate the sphericity assumption there are several corrections can be applied (Pallant, 2013). One of the ways to estimates sphericity used to correct the degrees of freedom is with Greenhouse and Geisser's (1958). Univariate test showed in Table 4.

Table 4: Result of Univariate for Achievement

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Achievement	Greenhouse-Geisser	222.840	1.561	142.719	101.266	0.000	0.674
Error (Achievement)	Greenhouse-Geisser	107.827	76.508	1.409			

Univariate test results based on Greenhouse-Geisser estimates of sphericity showed in Table 4, it was found that the main effects of the test time were significant for achievement towards genetics concepts (F = 101.266, p <0.05, η_p^2= 0.674). That Partial Eta Squared value, η_p^2 = 0.674 indicates that the size of the test time effects for achievement towards genetics concepts is very large (Cohen, 1988).

Significant multivariate test results as in Table 2 and univariate tests as in Table 4 showed that at least one test pair have a significant mean difference in the mean score of the achievement test towards genetics concepts. To determine the test pair which have the significant difference, the Sidak test was conducted. Table 5 shows the results of the Sidak Test.

Table 5: Result of Sidak Test for Achievement (Pairwise Comparisons)

Achievement		Mean Difference	Std. Error	Sig.*
Pretest	Posttest	-1.920	0.18	0.001
	Delayed Posttest	-2.940	0.26	0.001
Posttest	Pretest	1.920	0.18	0.001
	Delayed Posttest	-1.020	0.18	0.001
Delayed Posttest	Pretest	2.940	0.26	0.001
	Posttest	1.020	0.18	0.001

Based on estimated marginal means
*. The mean difference is significant at the 0.05 level

The results of the Sidak Test as in Table 5 indicate that significant differences (p <0.05) are found in the following three mean pairs of scores:

i.   Mean score of pretest on achievement towards genetics concepts with the mean score of posttest on achievement towards genetics concepts.
ii. Mean score of pretest on achievement towards genetics concepts with the mean score of delayed posttest on achievement towards genetics concepts.
iii. Mean score of posttest on achievement towards genetics concepts with the mean score of delayed posttest on achievement towards genetics concepts.

The mean score of pretest, posttest and delayed posttest of the achievement towards genetics concepts was significant (p=0.000). By applying Estimated Marginal Means Test on achievement towards genetics concepts, the pattern of mean differences can be obtained.

Table 6: Result of Estimated Marginal Means for Achievement

Achievement	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Pretest	5.90	0.31	5.28	6.52
Posttest	7.82	0.38	7.06	8.58
Delayed Posttest	8.84	0.37	8.09	9.59

The results in Table 6 shows the mean of pretest on achievement towards concept are 5.90 while the mean of posttest on achievement towards genetics are 7.82. This tells that there is an increase in the mean scores of the test on achievement towards genetics concepts due to intervention. The Sidak Test (Pairwise Comparisons) as showed in Table 5 showed that there is a mean difference between pretest and posttest is significant. Thus, there is no significant difference between mean score of pretests and mean score of posttests on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module is rejected. These results showed that Integrated STEM-PBL module gives a significant enhancement among undergraduates' achievement towards genetics concepts.

Finally, the mean score of the posttest on the achievement towards genetics concepts are recorded as 7.82 and there is a slight increase in the mean score of delayed posttest on achievement towards concepts, which are recorded as 8.84. The Sidak Test (Pairwise Comparisons) as showed in Table 5 showed that the mean difference between pretest and posttest is significant. Thus, there is no significant difference between mean score of posttests and mean score of delayed posttests on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module is rejected. These results showed that Integrated STEM-PBL module able to provide a positive retention effect on achievement towards genetics concepts after the intervention.

Based on the results above, there is no significant difference between the pretest, posttest, and delayed posttest on the mean score on achievement towards genetics concepts among first-year undergraduates following Integrated STEM-PBL module is rejected. It can therefore, best conclude that Integrated STEM-PBL module were able to give enhancement and positive retention on achievement towards genetics concepts among first-year undergraduates.

Discussion

The findings showed that Integrated STEM-PBL module able to enhance and retains the achievement towards genetics concepts. Significance hypothesis test results between pretest and posttest showed there is an increase in achievement towards genetics concepts after followed the Integrated STEM-PBL module in learning genetics concepts. The significance hypothesis results between posttest and delayed posttest showed there is retention in achievement towards genetics concepts after six weeks intervention ends.

As revealed by preliminary data of this study indicated that the respected faculty did not use any instructional materials to teach or learn genetics. A module as one of instructional materials can be used to learn science in Malaysia (Azman et al., 2018; Fadhilah et al., 2022). Using module cannot only increase the interest in learning science but also can improves undergraduates' achievement in science related course. The findings of this study have been supported by previous research has indicated that learning using STEM based instructional modules improves undergraduates' achievement in science (Osman et al., 2013; Rasul et al., 2017; Yasin et al., 2018).

One of the dependent variables of this study is to measure achievement towards genetics concepts in genetics course during second semester. Achievement is one of the concerns in the study because Becker, Horstmann, and Remington (2011) stated that one way to understand the effective way to implement STEM is by measuring students' achievement in learning science. This is also supported by McBride and Silverman (1991), which showed that the integration of STEM in the curriculum will increase students' achievement in the discipline of science, technology, engineering and mathematics. When the integrated STEM education makes learning more relevant and meaningful for students, it can improve students' attitudes towards STEM subjects, improve higher level thinking skills, and increase achievement (Stohlmann et al., 2012; Fadhilah et al., 2022; Cebesoy & Oztekin, 2018; Asfaw et al., 2022).

Apart from this, Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, and Wenderoth (2014) revealed that the examination performance increase by introducing undergraduates with STEM education, and the failure rates under traditional lecturing increase by 55% if remains the normal lecturing method. This study also encourages more undergraduates to receive STEM education through different ways so that the number of undergraduates receiving STEM degrees could be answered. Research by Haak, HilleRisLambers and Freeman (2011) was done when STEM instructors have been charged with improving the academic achievement and retention from diverse background. As outcome, Haak, HilleRisLambers and Freeman (2011) had suggested by introducing problem solving, data analysis, and other higher order cognitive skills will improve the performance and retention of students at higher institution in introductory biology class. Besides that, the implementation of integrated approach in STEM will not only be able to enhance the interest but it is revealed that integrated approach in STEM education with the topics that present problems in current life will be able to increase achievement of the course and thus will increase the number of students planning a career to STEM (Honey, Pearson & Schweingruber, 2014).

There is much recent emphasis on increasing the number of STEM graduates and the importance at higher education environment in promoting undergraduates' achievement in biology courses to allow them to success through STEM (Akiri & Dori, 2022; Huang et al., 2022; Geesa et al., 2022). Furthermore, this study used STEM based activities which integrate

science and mathematics or other contents areas through PBL. The steps of PBL are used as a way to learn STEM in the module, which might improve undergraduates' understanding. This is in line with previous studies by Hiong and Osman (2015), Yasin, Amin, and Hin (2018) which revealed that students' knowledge and achievement will increase through the PBL in the activities. Both of these previous researches had showed that the use of STEM based modules by designing work pieces improve students' knowledge and achievement. Besides that, study by Yasin, Amin, and Hin (2018) also had reported that interdisciplinary M-Biotech-STEM module for teaching in Biotechnology had improved students' achievement and 21st century learning skills in Malaysia.

From PBL activities, the students were encouraged to understand the real situations as situated learning context by analysing the conditions and constraints of challenges and then by searching relevant information for making decisions, designing possible solutions before presenting the best practice to the member of the class. All these processes were driven through assumed situated contexts which are important in learning process as found by Putnam and Borko (2000). In addition, students have to deeply understand each sub-concept in Stage 6, which is synthesis and application before they can reflection and get feedback in Stage 7.

Conclusion

The findings of this study are aligned with Maher (2004) which stated it is important that these outcomes not be so specific as to restrict their applicability for students' diverse needs. In need analysis, the genetics lecturers felt that the usage of the module might be able to enhance the learning outcomes throughout genetics course (Fadhilah et al., 2022). This is in line with Fairweather (2008) which stated that the student learning and interest in STEM subjects can be improved if the faculty could be convinced to restructure their practices even slightly by replacing the current approach with some other educational approaches that might become effective opportunities to the first-year undergraduate and subsequently to the faculty in bringing STEM gradually into practice in future. Thus, outcomes become a learning experience for the first-year undergraduates in their behavioural changes and learning outcomes do not become a benchmark for them to study harder.

Students at higher education institutions must facilitate the opportunity to learn in the ways which allows them to engage and enables them to reach their full potential and develop skills that will help them thrive in the future (Akiri & Dori, 2022). Thus, lecturers should be dynamic and adapt to various changes and yet hold on the basic concepts of higher education. A lecturer must diversify teaching and learning methods. In other words, as a lecturer they have to create the opportunity to unleash students' creative potential skills and innovation. Lecturers need to design the learning activities so that the students in higher education institutions able to identify their capabilities, strengths and weaknesses and those will not happen if only learning through lectures in a conventional setting. From need analysis, it revealed that the lecturers know the importance of implementation of STEM education, apart from the English proficiency. This is because STEM gain priority since it was highlighted in Malaysia Higher Education Blueprint (2015-2025). In this study, genetics lecturer will be the facilitator to facilitate the learning process for first-year undergraduates. They can use Integrated STEM-PBL module as a learning method to enhance the learning among the first-year undergraduates.

Moreover, this study provides evidence to support the development of lifelong learning skills for the 21st century like group work and self-directed learning, which are needed to support

STEM-PBL approach. By applying STEM-PBL approach, first-year undergraduates become more proficient in carrying out tasks cooperatively, working in groups effectively, accessing different resources, and identifying appropriate knowledge for learning issue (Ceylan & Ozdilek, 2015). First-year undergraduates are supported by the current study as they form hypotheses and work to discover answers to their questions. In addition, first-year undergraduates are encouraged to gather data to create new possible solutions (Ceylon & Ozdilek, 2015; Guzey, Moore & Harwell, 2016). Consequently, this study reduces lecturer-centered learning of traditional method and enhances student-centered learning of STEM-PBL approach as possible.

PBL as a student-centered curricular method, has significant potential for engaging first-year undergraduates in authentic STEM content through the active pursuit of workable solutions to real-world problems. The key findings in this study shows that the use of PBL in STEM context to learn genetics concepts able to enhance achievement, which can see in posttest and delayed posttest. Study findings showed that by using the researcher's developed Integrated STEM-PBL module had enhanced and retained the achievement in learning genetics concepts among first-year undergraduates in their second semester of study. Therefore, to maximize this positive impact of learning genetics using the PBL in STEM context, education policy should give attention to STEM education and support STEM learning engagement at higher education. This invariably will also provide undergraduates with ample opportunity to gain 21st century skills for solutions to real-world problems.

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