Comparison of Student Achievement in Agricultural Biotechnology-STEM Integrated Using Research Based Learning

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Abstract. Biotechnology has been widely used to meet the challenges of producing products in the current industrial revolution era 4.0. One of the trends in educational field to face the challenge is to integrate Science, Technology, Engineering, and Mathematics (STEM) altogether. The purpose of this study is to compare two models of STEM Research-Based Learning, that is, Project Based Learning (PjBL) and Aesthetic Student-Teacher Elaborate Research (ASTER). Fifty five students from two classes were selected through typical case sampling; class A was about 29 students taught using PjBL, whereas Class B was 26 students taught using ASTER. This study used quantitative data which were analyzed using t-test. The results indicated that learning achievement of both classes were not quite different, with ASTER (achievement of 48.3%) and PjBL (achievement of 45.5%). Therefore, this study suggests that further empirical studies need to be conducted on the effect of STEM integrated learning with the use of ASTER to strengthen the results of the study.

1. Introduction
Education in the 21st century increasingly emphasizes the importance of Science, Technology, Engineering and Mathematics (STEM) contributing to the development and growth of modern industrial society [1,2]. Advances in information technology and biotechnology are the two determinants of the current era [3]. In this context, the mastery of intelligence and biotechnology is one of the challenges facing a new era called the industry revolution 4.0 or the fourth world industrial revolution [4]. The existence of biotechnology has been widely used in various products throughout the 21st century [5]. Thus, preparing the quality of human resources in terms of innovation and meeting challenges of industrial revolution 4.0 is mandatory.

STEM education so called as STEM integrated learning is essential to modern education [7] and provides global competitiveness [8]. In this context, STEM integrated learning is a global movement in education, through various integration patterns to develop the quality of human resources, in line with modern-day demands [9]. Therefore, it becomes a trend in today's education [10].

To prepare competitive citizen, many countries around the world prioritize the quality improvement of science [11] and technology learning. One of the efforts to improve learning quality in Indonesia is to integrate STEM with the curriculum system in Indonesia [9]. In addition, STEM integrated learning can develop discipline knowledge, stimulate interest in STEM learning, as well as assist in future job-related skills [12]. Introducing STEM integrated learning to students is then an important component of the curriculum in the 21st century. Besides, STEM integrated learning in
higher education is needed to provide more support for innovative learning, such as in biotechnology lectures.

For decades the biotechnology has grown very rapidly [13]. Plant biotechnology allows the use of new genetic elements found to plant new varieties of agricultural crops with added value [14]. This leads to increase nutrition over fruits and vegetables. Agricultural biotechnology materials are one of the basic biotechnology course materials that is trying to develop steps of integrating STEM so as to students learn to deepen knowledge of science [15]. Producing Virgin Coconut Oil (VCO), for instance, involves students to do complex thinking as STEM mandated, such as, determining variables, choosing various techniques, calculating expenditure, and learning how to use apparatus to apply for.

In addition, there is also a new challenge for the development of life-based curriculum as well as biology practices that develop capabilities by integrating the mastery of content, attitudes, characters, values, management skills, and research. Therefore, the need for a learning approach can answer global challenges. The ability to think logical, critical, and creative become necessary to analyze and solve problems given to the students. Through this observation based learning activity, students will be accustomed to working in networking through collaborative learning to enhance student creativity. The research-based learning undertaken in research activities is a Project-Based Learning Model (PjBL) and Aesthetic Student Elaborate Research (ASTER).

PjBL is a form of constructivist learning and collaboration in the learning process of using student-centered learning, which enables students to work together to solve problems and learn from each other to build their knowledge from pieces of which. PjBL is a systematic learning that actively involves students in developing their knowledge and skills [17] and can motivate students to learn independently [18]. Problem-solving can also be done through the empowerment of various skills [19]. The use of projects in lectures has several advantages such as giving students the opportunity to link statistics with everyday life [18].

Different to PjBL models which deals with learning quality improvement [19], ASTER model is a model developed by researchers referring to the mix of the local wisdom of Patrap Triloka based on the Ki Hajar Dewantara Education Idea [20]. The teaching model tries to enhance the patrap triloka values of wisdom and the form of research activities to facilitate STEM education. ASTER itself can be defined as "sensitivity (patrap) of an educator (lecturer/teacher) in giving guidance (mentor) or stage in ngarso sung tulodo, coaching or stage in the middle of the game, and the motivation or the level of self-determination of students in the learning pattern (with research) is carried out together"

This research is important as an effort to harmonize students' competence with the needs of the community through the integration of STEM and the raising idea of Ki Hajar Dewantara. That way, forming itself to be able to challenge the times will continue to be an important consideration [21]. In short, the application of STEM integrated learning emphasizes the student's thinking ability in implementing interdisciplinary integration and intellectual achievements for science, technology, engineering and mathematics [22]. Therefore, the integration of STEM in the lectures is felt with urgency in planning learning activities.

Based on the above explanation, the purpose of this study compares learning achievement between PjBL and ASTER. The question asked in this study is how the difference in learning outcomes of students with Model PjBL and Aster Model on Agricultural Biotechnology materials?

2. Method
This research used a quantitative approach with post-test-only control group design, implemented at Science Department, State University of Surabaya. Participants of this study were second-year students taking General Biotechnology course in the third semester, academic year 2017/2018 from two different co-educational classes. To be precise, class one consist of 3 males and 26 females), while class two contains 4 males and 22 females. In addition, they have relatively the same economical background and ethnic.

The instrument developed in this study is written test used to measure the learning outcomes of relevant student knowledge. The STEM items of the instrument are as follows: (1) Science, the role of tissue culture of plant (score 15); (2) Technology, protoplast combination technology (score 20) and
utilization of devices water flow laminarly related to tissue culture (score 20); (3) Engineering, determination of research variables and product quality (score 20); and Mathematics, the effectiveness of manufacturing technique to produce VCO related to pricing (Score 25).

The data collected were analyzed using quantitative. In order to know the comparison results of PjBL and ASTER, the data were analysed using t-test with the aid of Minitab 16. Before the t-test was conducted, the initial data were tested for normality test using a histogram with fit and homogeneity test using Levene's test.

3. Results and Discussion

3.1. Overview of Research

Biotechnology is the fastest-growing industry in the production of commercial applications and products worldwide [13]. Thus, it has resonated with STEM's integrated learning as one of the solutions to human resource quality problems and the competitiveness of a country, both developed and developing countries [9]. Integrated learning in the STEM has a positive impact on student achievement [23] in terms of future STEM talent and competitiveness [12,7]. Descriptive statistical analysis results about both model STEM based are presented in Table 1.

Table 1. Descriptive Statistics of PjBL Model and Aster Model

| Variable     | N  | St-Dev | Mean | Median | Minimum | Maximum |
|--------------|----|--------|------|--------|---------|---------|
| PjBL Model   | 29 | 15.95  | 67.1 | 66.0   | 34.0    | 98.0    |
| Aster Model  | 26 | 13.80  | 68.2 | 71.0   | 36.0    | 88.0    |

Internationally, STEM's integrated learning can increase students' interest [24] and influence students to become technologically literate [7]. Related to the context of STEM, it is one of the key drivers of technological innovation [25]. One of the learning practices in Indonesia that can be developed is learning by integrating STEM [26]. Through this STEM integration, studies in learning will be more multidisciplinary [23]. However, the way to develop a sense of interest and curiosity with the world of disciplinary science is not an easy matter. This study then contributes to biotechnology learning that integrates this discipline so as to make students engage in critical, creative, and collaborative thinking. STEM stands for study or professional practice in science, technology, engineering, and mathematics [27]. STEM's integrated learning is an integrated education that combines scientific research, technology, engineering design, and mathematical analysis into a unified learning paradigm, including curriculum content, teaching activities, and educational policies. Integration pattern taken in this research activity is to unite engineering content (E) or engineering, and technology (T), as well as mathematical (M) learning in agricultural biotechnology. Incorporation visualization as illustrated in Figure 1.

Figure 1. Incorporation Of Technology, Engineering, And Mathematical In Agricultural Biotechnology Materials
In the context of this study, we define integrated STEM as a combination of content and concepts from multiple disciplines [28]. Integration takes place in STEM disciplinary knowledge and process [28] by which agricultural biotechnology not only produces vegetables and fruits but also offers an effective way of producing new value-added products with the potential to influence nutrition and human health.

3.2. Normality Test Results
The important assumption in parametric testing is normality. Paired sample normality checks performed with (1) histogram with fit (2) Chi-square, and (3) normalized test Kolmogorov-Smirnov [29]. In this research activity, the norm test used a histogram with fit described in Figure 2 and Figure 3.

![Figure 2. Histogram Test with Fit Normalized PjBL Model](image)

![Figure 3. Histogram Test with Fit Aster Normalized Model](image)

Normal data can be viewed descriptively by using the probability plot of the difference data above. Referring to figure 2 and 3, the data show a bell-shaped line with a normal distribution plot. In the upper right corner, it shows corresponding PjBL Model value $KS = 0.098$ and $p-value > 0.150 > \alpha = 0.05$. Likely, histogram of Aster Model the above figure shows that the result is relatively similar, with value $KS = 0.129$ and $p-value > 0.150 > \alpha =0.05$. Conclusions, data support for acceptance $H_0$ with a 95% confidence level.

3.3. Variance Homogeneity
Variant homogeneity test aims at checking the similarity of variances between the two populations [29]. Homogeneity can be interpreted to have the same variance, or in other words similar or nearly identical variants presented in Table 2.

| Table 2. Test Uniformity Using Levene Test |
|-------------------------------------------|
|                                           |
| F Test (normal)                           |
| PjBL Model                                | 28 |
| Aster Model                               | 25 |
| Statistic                                 | 1.34 |
| P-Value                                   | 0.468 |
| Levene's Test                             |
| PjBL Model                                | 1 |
| Aster Model                               | 53 |
| Statistic                                 | 0.25 |
| P-Value                                   | 0.25 |

Analysis of testing using Levene's Test shows homogeneous data $p \geq 0.05$. Results show that $F_{count} = 1.34$ dengan $p-value = 0.468 \geq 0.05 = \alpha$. So, the data supports to accept $H_0$ which means both variants of homogeneous data with a 95% confidence level.

3.4. Analysis of Range
Analysis of range shows the difference between the largest and the smallest value [29], where the distant values are far greater. On the other hand, if the values are relatively close, the size of the diversity tends to be small. PjBL Model is data range $95 - 35 = 60$. Aster Model is data range $88 - 36 = 52$. This shows that the PjBL model data range is higher than the Aster Model. In other words, PjBL model values are varied more than the Aster Model.
3.5. Achievement of Learning Indicators

Developmental Progress in the STEM is expected to be the driving forces of the future economy and overall well-being not only for developed country, but also for developing countries [30]. Integrated learning STEMs can relate to scientific investigations, by formulating hypothesis answered through research [31]. Therefore, this skill should be considered as the benchmark for graduates.

Table 3. Average Comparison of Learning Achievement Indicators PjBL Model and Aster Model

| No | Indicators                                                                 | PjBL | ASTER |
|----|---------------------------------------------------------------------------|------|-------|
|    |                                                                           | N=29 | N=26  |
| 1  | Describing the role of plant tissue culture from the aspect of medicinal   | 10.1 | 8.5   |
|    | benefits (Science).                                                       |      |       |
| 2  | Analyzing the effectiveness of the technique in producing Virgin Coconut   | 16.6 | 19.9  |
|    | Oil (VCO) in accordance with pricing (Mathematics).                        |      |       |
| 3  | Identifying the variables of the study and the determination of the       | 5.9  | 6.8   |
|    | quality of nata de corn (Engineering).                                     |      |       |
| 4  | Communicating the combined technique of protoplasts and tools related to   | 12.8 | 13.1  |
|    | the process of tissue culture cultivation (Technology).                    |      |       |
|    | Percentage                                                                | 45.4 | 48.3  |

The biotechnology sector is one of the key strategy that will transform into a developed nation by 2020 [13]. Biotechnology has grown rapidly, particularly in agriculture and livestock, food and pharmaceutical industry [16] through interdisciplinary approach [32]. The implications for STEM include how they can narrow the gap between education and workplace competencies [27].

4. Conclusion

This research presents the empirical evidence that the learning achievement trends in the aster model (achievement of 48.3%) are higher than PjBL (achievement of 45.5%). Although the use of these two models is considered to be ineffective in achieving the completeness of student learning (<50%), the implementation of this model is considered to be equivalent to an empirically proven PjBL model that can improve the quality of learning. The implication of this study is that the Model PjBL and Aster Model can be used as an alternative to implementing research-based learning process on agricultural biotechnology courses. It is evident that the Patrap Triloka gesture developed into the potential Aster model and can be regarded as a learning model that can enhance STEM's integrated material control.

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6. References

[1] León J, Núñez J L and Liew J 2015 Learn. Individ. Differ. 43 pp 156–63
[2] Le H and Robbins S B 2016 J. Vocat. Behav. 95–96 21
[3] Suwono H, Lestari U, Lukiat B and Lestari S R 2018 Int. Conf. on Learn. Innov. (ICLI 2017) 164 97
[4] Kemristekdikti 2018 Presiden Jokowi: Tantangan Kita Kedepean, Revolusi Industri 4.0 pp 1–2
[5] Bahri N M, Suryawati E, and Osman K 2014 Eurasia J. Math. Sci. Technol. Educ. 10 195
[6] Widayati D T, Luknanto D, Rahayuningsih E, Sutapa G, Harsono, Sancayaningsih R P and Sajarwa 2010 Padoman Umum Pembelajaran Berbasis Riset STAR
[7] Kanematsu H and Barry D M 2016 STEM and ICT Education in Intelligent Environments (London: Springer)
[8] Christensen R 2015 J. Sci. Educ. Technol. 24 898
[9] Firman H 2015 Pendidikan Sains Berbasis STEM: Konsep, Pengembangan, dan Peranan Riset Pascasarjana Seminar Nasional Pendidikan IPA dan PKLH (Bogor: Pendidikan IPA Program Pascasarjana Universitas Pakuan)
[10] Pellas N, Kazanidis I, Konstantinou N and Georgiou G 2017 Educ. Inf. Technol. 22 2235
[11] Guzey S S, Moore T J, Harwell M and Moreno M 2016 J. Sci. Educ. Technol. 25 550
[12] Lai C S 2018 J. Educ. Sci. Environ. Heal. 4 110
[13] Bahri N M, Suryawati E and Osman K 2014 J. Math. Sci. Technol. Educ. 10 195
[14] Ricoch A, Surinder C and Fleischer S J 2014 Plant Biotechnology: Experience and Future Prospects (London: Springer)
[15] Lou S, Chou Y C, Ru-Chu S and Chih-Chao C 2017 Eurasia J. Math. Sci. Technol. Educ. 8223 2387
[16] Suwono H, Lestari U, Lukiat B and Lestari S R 2018 Adv. in Soc. Sci. & Humanit. Res. 164
[17] Suman W, Wardani S and Gupitasari D N 2016 J. Pendidik. IPA Indones. 5 157
[18] Mairing J P and Lorida D 2013 J. Pendidik. 14 53
[19] Hernawati D, Amin M, Irawati M, Indriwati S and Aziz M 2018 Eurasia J. Math. Sci. Technol. Educ. 14 2475
[20] Subekti H 2018 Model Pengajaran ASTER (Aesthetic Student-Teacher Elaborate Research): Sebuah Model Pengajaran Berbasis Kearifan Lokal Patrap Triloka Terintegrasi STEM Education Untuk Mengembangkan Keterampilan Riset, Literasi Informasi, dan Komunikasi Sains pp 1–50
[21] Ames T, Reeve E, Stewardson G and Lott K 2017 Preferred J. Technol. Educ. 28
[22] Tsai H Y, Chung C C and Lou S J 2018 Eurasia J. Math. Sci. Technol. Educ. 14 15
[23] Mayasari T, Kadarohanma A and Rusdiana D 2014 Pengaruh Pembelajaran Terintegrasi Science, Technology, Engineering, and Mathematics (STEM) pada Hasil Belajar Peserta Didik: Studi Meta Analisis Seminar Nasional Pendidikan IPA VI ed W Widodo, Erman and E Sudibyo (Surabaya: Unesa University Press)
[24] Kier M W, Blanchard M R, Osborne J W and Albert J L 2014 Res. Sci. Educ. 44 461
[25] Goy S C, Wong Y L, Low W Y, Nurani S, Noor M, Onyeneho N, Daniel E, Azizan S and Ginikauzoigwe A 2017 Stud. High. Educ. 0 1
[26] Khaeroningtyas N, Permasasari A and Hamidah I 2016 J. Pendidik. IPA Indones. 5 94
[27] Jang H 2016 J. Sci. Educ. Technol. 25 284
[28] Nadelson L S and Seifert A L 2017 J. Educ. Res. 110 pp 221
[29] Mairing J P 2017 Statistika Pendidikan: Konsep dan Penerapannya Menggunakan Minitab dan Microsoft Excel ed Seno (Yogyakarta: ANDI)
[30] Al-Salami M K, Makela C J and de Miranda M A 2017 Int. J. Technol. Des. Educ. 27 63
[31] Kelley T R and Knowles J G 2016 Int. J. STEM Educ. 3 1
[32] Barak M and Assal M 2018 Int. J. Technol. Educ. Des. 28 pp 121