www.bircu-journal.com/index.php/birci
Budapest International Research and Critics Institute-Journal (BIRCI-Journal)
Humanities and Social Sciences
ISSN 2615-3076 Online)
ISSN 2615-1715 (Print)
Budapest Institute

The Effect of Constructivism-Based STEM on Students' Creative Thinking Skills in Biotechnology Learning

Yustina[1], Imam Mahadi [2], Zulfarina[3], Oky Priawan[4], Diana Anggraini[5]
[1,2,3,4,5]*Faculty of Teacher Training and Education, Universitas Riau, Indonesia*
yustina@lecturer.unri.ac.id, imam.mahadi@lecturer.unri.ac.id, zulfarin@yahoo.co.id

Abstract

Fish feed biotechnology is fish pellets produced through the fermentation process of mustard greens, fats, and used cooking oil from waste containing vegetable nutrients. The results of this preliminary research were developed into leaflets and booklets as teaching materials for student learning guides through the constructivism-based STEM approach. This research was conducted at SMP Purnama Pekanbaru from February to April 2020 with a one-group pretest-posttest experimental research design. The research subjects were 25 ninth-grade students who took biotechnology extracurricular activities. The data were collected using the students' creative thinking ability test sheets. Scores and mean scores of data were calculated, tabulated, and analyzed descriptively. The research objective was to analyze the effect of the constructivism-based STEM approach on students' creative thinking skills. The results showed that learning using the constructivism-based STEM approach effectively improved students' creative thinking skills in biotechnology learning in recycling waste into fish pellets.

Keywords
creative thinking skills; fish pellets; constructivism-based STEM

I. Introduction

The rapid global development due to technological advances requires the world's nations to change their education systems. In recent years, both developed and developing countries have sought to improve education quality with the Integrated Thematic Instruction (ITI) model. Thematic learning has scientifically shown its success in accelerating and increasing students' memory capacity. Therefore, teachers are required to follow the latest developments, including the approach to the learning process.

According to Sunarno (2019), the science learning strategy in the classroom must contribute to building creative character for the next generation that is reliable in the future. The expected generation is superior, innovative, which reinforces the creative economy. In this case, it can be done with project-based science learning with a STEM approach that can empower students' creativity. Creativity means finding a way out of old ideas to find new ideas, developing potential (Wahyudi et al., 2018), turning problems into opportunities (Reality, 2018), dynamic activities involving mental and brain processes aware (Widana & Wirabayu, 2017).

Creative thinking skill is needed in understanding the essence of life or life itself, skilled in solving life's problems and living life in a balanced and harmonious manner. This skill will be optimal if teachers are skilled at developing research-based learning materials because learning will be easier to understand and meaningful for students (Yustina, 2019). Science education should help students in science development, make decisions about science issues and their impact on community technology, and enrich scientific knowledge (Suwono et al., 2017).

The leaflet of making fish feed is one of the initial research outputs of this series of studies. This leaflet can be developed to guide students on learning biotechnology materials to experience and be skilled in making fish pellets by utilizing waste. This biotechnology material is carried out in extracurricular learning activities through a constructivism-based STEM approach. It is in line with constructivism that student knowledge results from students' constructions through a series of students' activities through assimilation and accommodation. The application of constructivism from scientific research can increase creativity (Yustina & Danilsyah, 2015).

In line with Subekti's (2018) research, high-level skills, scientific literacy skills are relevant to society's needs and opportunities for students to develop themselves, such as continuing their studies, personal development. It follows constructivism implementation in understanding and building concepts and skills in connecting concepts with new knowledge (Yustina, 2019) and related to the five STEM implementation principles (Tibaut L et al., 2018).

The constructivism-based STEM approach systematically constructs knowledge, concepts, and some skills to solve problems, reformers, inventors, logical thinking, and technological literacy (Subekti, 2018). It indicates that the constructivism and STEM approaches can synergize with each other in the learning process. From observations, research on constructivism-based STEM has not been encountered by researchers.

Based on the description above, this study aimed to analyze the effect of Constructivism-Based STEM learning on students' creative thinking skills. This research helps improve the quality of biotechnology learning in recycling waste (vegetables and used cooking oil) as additional material in the manufacture of fish pellets. The products can be an alternative home industry business or feed in fish farming for students.

II. Research Method

2.1 Place and Time of Research

This quasi-experimental research was conducted from February to April 2021 at SMP Purnama Pekanbaru, Riau Province.

2.2 Research Subject

The research subjects were students of SMP Purnama Pekanbaru in the 2020-2021 academic year. With the purposive sampling technique, 25 students from biotechnology extracurricular activity were chosen.

2.3 Research Design

The research design used was a pretest-posttest single group design. The design is as follows:

Pretest	Treatment	Posttest
M_1 Y_0	$M_{1,2}$	M_3Y_1

Information:
$M_{1,2}$: Treatment of Constructivism-based STEM learning
M_1: Creative thinking skills before treatment M_3: Creative thinking skills after treatment
Y_0: Pretest before treatment Y_1: Posttest after treatment

2.4 Research Parameter

Research parameters are students' creative thinking abilities which consist of 4 aspects: fluent thinking, flexible thinking, original thinking, and elaborative thinking.

2.5 Research Procedure

The research procedure is presented in Figure 1.

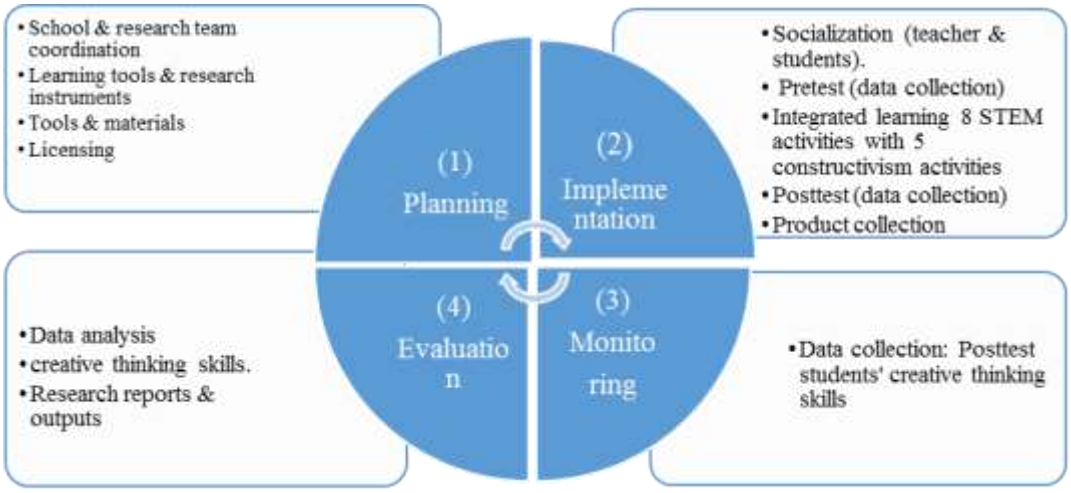

Figure 1. *Research Procedure for Integration of Constructivism-Based STEM Approach*

2.6 Data Collection and Analysis Techniques

Data collection and analysis techniques are as follows:

Written test is carried out at the beginning of learning with pretest and posttest at the end of learning. This instrument was used to assess students' creative thinking skills. An expert team first validated the questions used in the test. The data obtained were calculated for each component, and the average score was calculated. Data in the form of scores were converted into values. The score was divided by the maximum score multiplied by the maximum value (100).

The data used were normalized Gain Index and classification/effectiveness to determine the increase in creative thinking competence (Hake, 1999). The average normalized gain value (Gain index) is the difference between the average score of the final test (posttest) divided by the difference between the maximum score minus the average pretest score. Interpretation of normalized gain index (g) and classification referring to Hake (1999) is shown in Table 1.

Table 1. Index Score and Classification/effectiveness

Normalized Gain Index	Classification
$(g) \geq 0{,}70$	High/very effective
$0{,}30 \leq (g) \geq 0{,}70$	Medium/effective
$(g) < 0.30$	Low/less effective

The gain index (g) was interpreted according to the classification of Hake, R. (1999). The following shows a constructivism-based STEM creative thinking indicator pattern and a grid of creative thinking assessment questions (Table 2).

Table 2. Constructivism-based STEM Creative Thinking Indicator Pattern And A Grid Of Creative Thinking Assessment Questions

Constructivism Activities and STEM	Sub-indicator of Creative Thinking Activities	Score				Field	Creative Thinking Indicator and Question Number
		1	2	3	4		
1. Orientation / direction (1) Ask questions, determine the type of material, the pellet material content, the theme, the objectives, the benefits, and the relevant fields in the activity.	1.1. Describe the types of pellets and their contents					Science	Curiosity (asking, answering, and responding) B. Fluent (4 items) 1,2,3,4
	1.2. Classify the types and composition of fish pellets.						
	1.3. Group the fields of science related to the manufacture of pellets appropriately.						
	1.4. Understand the theme, purpose, and benefits of the activity.						
II.Giving ideas (2,3) Plan and develop designs, and use models	2.1.Data display on the type of material and content.					Engineering	Come up with ideas & ask relevant questions B. original (4 items) 5,6,7,8
	2.2 Display of pellet composition data						
	2.3. Skilled in designing fish pellet manufacturing procedures						
	2.4. Use a computer to display data precisely.						
III. Idea structuring (3,4.5,6) Determine and use computational pelletizing tools and calculations.	3.1. Apply and determine the size of the pelletizer.					Technology and Mathematic	Provide ideas / suggestions, alternative / viewpoint answers to achieve goals B. flexible (4 items) 9,10,11,12
	3.2 Assemble tools appropriately.						
	3.3 Operate tools.						
	3.4. Skilled computing (using a computer) to count (analyze data).						
IV. Ideas application (7) Conduct arguments from evidence	4.1. Describe the details of the fish pellet manufacturing process based on the composition of the ingredients and contents					Science	Get products and improvements (B.orisinil / Elaboration) (2 Items) 13.14 Look at the product from various aspects B. Elaboration (3 items) 15,16,17
	4.2. Describe the details of the advantages, advantages, and benefits of making fish pellets						
V. Reflection (8) Obtain, evaluate, and communicate	5.1 Build a detailed description of the determinants of pellet quality.						
	5.2 Evaluate other alternatives to overcome the shortcomings.						
	5.3 Communicate / predict the opportunities and constraints of pellet business.						
Total Average Score							

III. Results and Discussion

Students' creative thinking skills based on pretest (before implementation) and posttest scores (after implementation) of the constructivism-based STEM approach are presented in Table 3.

Table 3. The average test score of students' creative thinking, n-gain index, classification interpretation in biotechnology learning through the constructivism-based STEM approach.

No	Creative Thinking Indicators	Average Score of Creative Thinking		n-Gain Index	Classification Interpretation
		Pretest	**Posttest**		
		Value (Category)	**Value (Category)**		
1	Fluent Thinking	60 (enough)	85 (very good)	0,6	Medium/Effective
2	Flexible Thinking	55 (poor)	67 (enough)	0,3	Low/Less Effective
3	Original Thinking	40 (poor)	68 (enough)	0,5	Medium/Effective
4	Elaborative Thinking	33 (very poor)	60 (poor)	0,4	Medium/Effective
Average		**47 (poor)**	**70 (enough)**	**0,4**	Medium/Effective

Based on table 3, the pretest value of creative thinking skills before implementing constructivism-based STEM approach learning and posttest after implementation has an average of 47 and 70 respectively and are categorized as effective in increasing creative thinking skills. Details of students' creative thinking skills in implementing constructivism-based STEM approach learning are as follows.

3.1 Fluent Thinking Indicator

Based on the fluent thinking indicator, the average posttest score obtained increased from 60 to 85 and was classified as effective in increasing the fluent thinking skills. In orientation activities, students were challenged by the teacher with guiding questions and explore students' initial knowledge of science in introducing the ingredients, the content of fish pellets, and the purposes and benefits of making fish pellets. In this activity, a common perception was prepared to prevent misconceptions in students.

The teacher explores students' curiosity through critical thinking stimulus questions: analyzing, interpreting, and assessing which emphasizes the active role of students in developing understanding with their knowledge. This shows that constructivism-based STEM learning is effective in increasing fluent thinking skills. Questions based on fluent thinking indicators are made to stimulate students to be willing to provide various kinds of answers. Students think fluently need critical thinking to solve problems, oriented to real action through empirical learning (Zainuddin & Attaran, 2015). It is supported by activities with appropriate, targeted, and integrated teacher stimulus strategies through the constructivism-based STEM approach, increasing student motivation (Yustina, 2020).

3.2 Flexible Thinking Indicator

The indicator of flexible thinking on posttest in the control class also increased. The average value obtained in the posttest is 67, and the pretest gets a value of 55 with a less effective classification of increasing flexible thinking. It starts from structuring ideas and answering teacher questions through stimuli, students issuing ideas to answer related to determining tools, arranging tools, and operationalizing tools related to technology. It is necessary to connect the concept according to the student's point of view because it has

flexible thinking skills, providing various interpretations of an image, story, or problem and generate varied ideas. It shows that the constructivism-based STEM approach is less effective in increasing flexible thinking skills because students are not used to giving a complete variety of answers from various technical skills that have been prepared following the activity procedure guide. These technological skills show that students are not technically skilled in operating the tools in making pellets. Luthfiyani et al. (2019) and Yustina et al. (2019) stated that the technology literacy of students in the classroom carrying out STEM-based biology learning is not significantly different from students in non-STEM classes because the STEM approach is something new for teachers and students so that it takes time to adapt to implement it optimally. According to Bhowmik et al. (2016), variations in learning activities can produce students' very flexible thinking skills, which require time to be realized.

3.3 Original Thinking Indicator

The indicator of original thinking in the control class has an average posttest of 68 and an average pretest score of 40. The value is classified as effective, which means that the constructivism-based STEM approach effectively improves students' original thinking. Structuring ideas, questions, and assignments of teachers, planning and carrying out activities that require students' engineering skills to rearrange ideas, develop, use models, design tables, graph the composition of the type of pellet material, and work procedures for making pellets.

The indicator requires students not to provide answers from their findings optimally because students are not used to finding new things or answering with variations in answers and using their sentences without copying the sentences in the book. Utami et al. (2016) stated that original thinking causes a person to give birth to new expressions.

3.4 Elaborative Thinking Indicator

The posttest average score of the elaborative thinking indicator was 56, which was increased compared to the pretest of 33, and was classified as less effective. It means that the constructivism-based STEM approach is less effective in increasing students' elaborative thinking. In this elaboration indicator, students are less able to detail and develop a concept of learning material during the application of ideas, make arguments from the evidence that has been implemented and its relation to other alternative phenomena.

In the reflection activity related to obtaining, evaluating, and communicating, there are the following questions: "What is your opinion be if vegetable ingredients were replaced with palm kernel?" and "What are your efforts to get the pellets floating?" It shows that students cannot select information according to their needs, and students' skills are only sufficient to answer, ask, or deal with a problem.

The following details of creative thinking present pellet-making procedures, data analysis techniques, and slow data processing. From the stage of giving stimulus to a presentation, the elaborative thinking indicator is the highest level indicator among other indicators. Usually, this stage takes a long time. The indicator of creative thinking skills is given a weighted value. The elaborate thinking indicator has the greatest difficulty because, in this indicator, students always try to develop an idea or product from existing ones and try to add or detail more details to be more interesting than before. The increase in the value of creative thinking skills is also supported by several factors, including the role of the teacher as a facilitator to encourage students to learn independently as much as possible so that students become more motivated to be more active in finding material

concepts, which will train students' creative thinking skills. Education is a very important human need because education has a duty to prepare Human Resources (HR) for the development of the nation and state (Pradana et al, 2020). According to Astuti et al (2019) Education is an obligation of every human being that must be pursued to hold responsibilities and try to produce progress in knowledge and experience for the lives of every individual. Education is one of the efforts to improve the ability of human intelligence, thus he is able to improve the quality of his life (Saleh and Mujahiddin, 2020). This is according to the opinion of Dziuban et al. (2018), that positive education plays a role in helping students communicate effectively and informational ideas, think flexibly and in detail.

Overall, students' creative thinking skills increase due to the five principles of STEM implementation (Tibaut et al., 2018): 1) creative understanding of definitions, concepts, and relationships with challenging tasks between differences in STEM disciplines; 2) interactively adjust and organize learning outcomes between different disciplines; 3) determine the choice of outputs and their relation to new learning outcomes; 4) the teacher estimates the time requirements in implementing integration and 5) collaboration between disciplines.

Furthermore, the activity pattern of the constructivism-based STEM approach is related to the proficiency of teacher instruction as a facilitator: (1) begins with guiding questions that challenge students' curiosity as a stimulus for students' fluent thinking; (2) statements and stimulus questions explore the origin of ideas or knowledge of original thinking related to the students' initial knowledge about the design/model of work procedures; (3) structuring ideas, questions and assignments of teachers, planning and carrying out activities / investigations that require technological, mathematical and flexible thinking skills to rearrange ideas related to work procedures; (4) applying ideas, making arguments based on detailed evidence (elaborative thinking) of the process of making fish pellets based on material composition and nutritional content, then (5) reflecting on evaluating, and communicating product quality and other alternatives to overcome shortcomings as well as predictive analysis of business opportunities.

The constructivism-based STEM approach fulfills all aspects that support improving the quality of learning in increasing creative thinking skills, but in its application, it has its challenges, including original thinking in designing and elaborative thinking. Winda et al. (2017) stated that educators must have the ability or skills in using technology and require much time in developing this STEM approach, especially at the beginning of the implementation period to build material that is following the learning method and process to answer and provide statements in class discussions.

IV. Conclusion

Based on the data analysis, the constructivism-based STEM approach effectively improves creative thinking skills in biotechnology learning in grade 9 students who take extracurricular activities at SMP Purnama Pekanbaru, but it is less effective in improving elaborative thinking skills.

References

Andrew Denis. 2016. *The Effectiveness of Science, Technology, Engineering and Mathematics (STEM) Learning Approach Among Secondary School Student*, Universiti Malaysia Sabah

Astuti, R.W., Waluyo, H.J., and Rohmadi, M. (2019). Character Education Values in Animation Movie of Nussa and Rarra. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*. P. 215-219.

Bhowmik Jahar, Meyer, Denny and Philips, Brian. 2016. *Blended Learning in Postgraduate Applied Statistics Programs*. *Proceedings of the Ninth Australian Conference in Teaching Statistics.*Canberra, Australia.

Charles Dziuban, Charles R. Graham, Patsy D. Moskal, Anders Non*berg* and Nicole Sicilia. 2018. International Journal of Educational Technology in Higher Education, 15 (3), pg 1-16. Do.10.1186 / s41239-017-0087-5.

Duran, M., Medjahed, B., Lawson, D.B., & Orady, E.A. 2016. *STEM Learning*: *IT Integration and Collaborative Strategies*. London; Springer.

Farah Robi'atul Jauhariyyah, Hadi Suwono1, Ibrohim. 2017. *Science, Technology, Engineering and Mathematics Project Based Learning* (STEM-PjBL) pada Pembelajaran Sains. Prosiiding Seminar Pend. IPA Pascasarjana UM, Vol. 2, 2017: 432-436. ISBN: 978-602-9286-22-9.

Firman, H. 2015. *Pendidikan Sains Berbasis STEM; Konsep, Pengembangan, dan Peranan. Riset Pascasarjana*. Paper presented at the Seminar Nasional Pendidikan IPA dan PKLH Program Pascasarjana Universitas Pakuan Bogor. http//www.academia.edu/21597075/.

Hake,R. 1999. Analizying Change/ Gain Score. (*online*) Tersedia: http://lists.asu.edu (2 Februari 2018).

Herak, R., & Lamanepa, G. H. (2019). Meningkatkan Kreatifitas Siswa melalui STEM dalam Pembelajaran IPA Increasing Student Creativity through STEM in Science Learning. *EduMatSains: Jurnal Pendidikan, Matematika dan Sains*, *4*(1), 89-98.

Pradana, D. A., et al. (2020). Nasionalism: Character Education Orientation in Learning Development. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)* Volume 3, No 4, Page: 4026-4034.

Realita, N. 2018. Era of Industrial Revolution 4.0, PT Learning Must Be More Innovative. Retrieved frominnovative/ http://sumut.pojoksatu.id/2018/01/17/era-revolusi-industri-4-0-pelajar-pt-harus-lebih-in.

Saleh, A., Mujahiddin. (2020). Challenges and Opportunities for Community Empowerment Practices in Indonesia during the Covid-19 Pandemic through Strengthening the Role of Higher Education. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*. Volume 3, No 2, Page: 1105-1113

Subekti, H., Taufiq.M, Susilo, H., Ibrohim, Suwono.H. 2018. Mengembangkan Literasi Informasi Melalui Belajar Berbasis Kehidupan Terintegrasi STEM Untuk Menyiapkan Calon Guru Sains Dalam Menghadapi Era Revolusi Industri 4.0; Revieu Literatur. Education and Human Development Journal 3 (1): 81-90.

Suwono, H., Pratiwi, H.E., Susanto,H. & Susilo, H. 2017. *Enhancement of Students Biological Literacy and Critical Thinking of Biology Through Socio-Biologicalcase-Based Learning*. Jurnal Pendidikan IPA Indonesia, 6(2), 213-220. doi: 10.15284/jpii.v6i2.9622.

Tibaut,L., Ceuppens,S.,De Loof,H., De Meester,J.,Goovaerts,L.,Struyf,A.,Boeve-de Pauw.,Dehaene,W.,Deprez,J.,DeCock,M.,Helliincks,L.,Knipprath,H.,Langie,G.,Stru

yven,K.,Valde,D.,Van Petegern,P. And Depaepe,F. 2018. Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. European Journal of STEM Education, 3(1),02. https://doi.org/10.20897/ejsteme/85525.

Wahyudi, Indri Anugraheni, and Adi Winanto. (2018). Development of Project-Based Blended Learning Models to Support Student Creativity Designing Elementary School Mathematics Learning. *Scientific Journal of Mathematics Education*. 6 (2) 68-21

Wayan Widiana., Gede Wira Bayu and I Nyoman Laba Jayata, 2017. Brain Based Learning, Cognitive Style for Creative Thinking Ability and Student Learning Outcomes. *Indonesian Education Journal.* Vol. 6, No.1.

Winda Wijayanti, Nengah Maharta, Wayan Suana.2017. Development of Devices *Blended Learning* Based on *Learning Management System* on Dynamic Electric Material. *Al-BiRuNi Physics Education Scientific Journal* 06 (1). 1-12

Widha Sunarno.2019. Pembelajaran IPA di Era Revolusi Industri 4.0 (Peran Pendidik dan Ilmuwan Sains dalam Menyongsong Revolusi Industri 4.0). Prosiding Seminar Nasional Pendidikan Fisika IV 28 Juli 2018: hal: 1 – 7. ISSN : 2527-6670 . *http://e-journal.unipma.ac.id/index.php/snpf*

Yustina .2020. The Effectiveness of Constructivism-based STEM Learning on Student Motivation and Learning Activity. URICSE Journal of Physics: Conference Series 1655 (2020) 012050. doi:10.1088/1742-6596/1655/1/012050

Yustina, Nursal, I. Suharman, A. Riandra, O. Priawan, & W. Sari. 2019. Implementasi Sains Teknologi Engineering dan Matematika (STEM) berbasis kewirausahaan budidaya lele dumbo dengan media bioflok dan pakan Bungkil Inti Sawit (BIS) di SMP Purnama Pekanbaru. Unri Conference Series: Community Engagement 1: 401-410 https://doi.org/10.31258/unricsce.1.401-410

Yustina. 2019. Implementasi konstruktivisme Dalam pembelajaran biologi (lingkungan hidup). ISBN 978-979-792-940-4. unri_press@yahoo.co.id.

Yustina and Danilsyah. 2015. Creativity of SM3T Participants, Riau University, Indonesia in Developing Knowledge Using Project-Based Learning at Lany Jaya, PAPUA, 86. Indonesia. Australian Journal of Basic and Applied Sciences. 9 (31): 530-536.

Zainuddin, Z, & M. Athtaran. 2015. *Malaysian Students' Perception of Flipped Classroom: A Case Study Innovation in Education and Teaching International*. 53 (6) .660-670.