The Effectiveness of Constructivism-based STEM Learning on Student Motivation and Learning Activity

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Abstract: Research to examine students’ motivation and learning activities through constructivism-based STEM learning has been carried out from January to April 2020 at “SMP Purnama Pekanbaru”. The design of one group used a purposive sampling technique, that is class IX which chooses extracurricular biotechnology. Data collection used observation sheets of learning activities and questionnaire sheets about student learning motivation. Data of frequency and percentage is calculated and analyzed descriptively. The results show that learning biotechnology through the constructivism-based STEM approach is effective in increasing motivation and recycling activities of waste into fish pellets.

1. Introduction
Integrated Thematic Instruction (ITI) is one alternative model to improve the quality of education to answer the challenges of progress in the fields of science and technology. Biology is the central science and principle in everyone’s daily life. Biology teachers and students need to be equipped with biological understanding and critical thinking skills to teach biology [1]. In line with the rapid progress in the field of science and technology, the teacher is required to follow the latest developments including the approach in the learning process to prepare graduates who can compete and adapt to change.

Integrative Thematic Instruction is a combination of four main areas in education, namely science, technology, engineering, and mathematics (STEM). STEM-based learning approach can improve scientific literacy, motivation, material understanding, creative thinking abilities, and meaningful learning [2]. The ability to think creatively is needed in understanding the nature of life or life itself. This ability will be optimal if there is motivation to learn [3]. Learning motivation increases in contextual learning with a constructivism approach [4].

Fish feed manufacturing leaflet is one of the initial research outcomes of this research series. This leaflet can be developed to guide students on learning biotechnology materials. So, students can experience and be skilled in making fish pellets by utilizing waste. The biotechnology material was implemented in an extracurricular learning activity through constructivism-based STEM approach. Teachers must be skilled in developing learning materials based on research results because learning will be more readily understood and meaningful for students [19]. Constructivism emphasizes that knowledge is formed through a series of activities, built by students through the process of assimilation (absorption of new information in the mind) and accommodation (rearranging the structure of the mind due to new information). The application of constructivism from science research can form a positive attitude [5], enhance creativity [6], and apply science concepts through LKPD [7].
In line with the statement [8], high-level skills, scientific literacy skills are relevant to the needs of the community and students. This, following the implementation of constructivism in understanding and building concepts and skillfully linking concepts with new knowledge [19], and related to the five principles of STEM implementation, namely: 1) creatively understanding definitions, concepts, and relationships with the task of challenging the differences between STEM disciplines; 2) interactively adjust and organize learning outcomes between different disciplines; 3) determine the choice of outcomes and their relation to new learning outcomes; 4) the teacher estimates the need for time in the implementation of integration and 5) collaboration between scientific disciplines [8].

Through a constructivism-based STEM approach to systematically constructing knowledge, concepts, and some skills can solve problems better, innovator, inventor, logical thinking, and technological literacy [9]. This indicates that the constructivism and the STEM approach have the potential to work together in the learning process. From observations, research on the integration of constructivism-based STEM has not yet been encountered by researchers.

Based on the description above, the purpose of this study is to examine the effectiveness of learning through the constructivism-based STEM approach on students’ motivation and learning activities and being useful in efforts to improve the quality of biotechnology learning in recycling waste into fish pellets, as an alternative home industry for students.

2. Research Method
This quasi-experimental study was carried out at SMP Purnama Pekanbaru in Riau Province from January to March 2020 with a purposive sampling technique, namely a group of class IX students in the Biotechnology Extracurricular activity, set by 25 respondents.

The study design was an experimental one group pre-test-post-test (Figure 1). This study contains two variables; The independent variable is learning using the STEM approach based on constructivism, the dependent variable is student learning motivation and student learning activity. Figure 1, as follows:

| Pre-test Y₀ | Treatment M₁,₂ | Post-test Y₁ |
|-------------|----------------|-------------|

**Figure 1. One Group Pretest-Posttest Design**

Information:
M₁,₂: Treatment of STEM learning based on Constructivism
Y₀: Giving pre-test before treatment
Y₁: Giving post-test after treatment

2.1 Data analysis and methods as follows:

2.1.1 The motivation questionnaire sheet compiled in this study is a closed questionnaire sheet with 4 Linkert scales, student learning motivation consists of 5 indicators, namely desire and curiosity, encouragement and learning needs, hopes and ideals, appreciation in learning and interesting activities in learning. Questionnaire motivation for student learning used the STEM approach based on constructivism. The assessment questionnaire sheet is according to Curriculum 2013. The five indicators are developed into descriptors and then elaborated in 15 statement items, each indicator consisting of 3 statement items. Learning motivation questionnaire is given before and after learning, the questionnaire descriptors are as follows,

**Table 1. Indicators and Descriptions for student learning motivation questionnaires**

| Indicator                      | Descriptor                                                                 |
|-------------------------------|---------------------------------------------------------------------------|
| Desire and curiosity          | Desire and curiosity to learn new information and learning tools.          |
| Encouragement and needs in learning | Facilitating educators, need support, feeling proud of the results achieved. |
| Hopes and goals of the        | Strive, persevere (intensity of learning) and optimistic (confident) in    |

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future completing tasks and relevant to the achievement targets in learning.

Appreciation in learning Giving and informing values, achievements, opportunities for competition.

Interesting activities in learning Attitudes of educators and peers towards students during learning, the material is relevant to the daily life of students, learning is facilitated in a fun, clear, direct, and easy to understand.

2.1.2 Indicators of learning activities are adjusted to STEM learning activities [10] and learning activities using the constructivism approach [19]. Learning activities are developed into STEM descriptors based on constructivism, activities, and observational descriptors (Table 2) as follows.

| No | STEM Learning Activities | Unit | Constructivism Learning Activities | Descriptors of Constructivism-based STEM Integration Activities |
|----|--------------------------|------|------------------------------------|---------------------------------------------------------------|
| (1) | Asking questions         | S    | Orientation                        | What, pellets, materials, ingredients, what are the themes & objectives, the significance of learning? |
| (2) | Developing design, model | E    | Making idea                        | Making material table, pellet composition, making a flow chart of making pellet |
| (3) | Planning and carrying out investigations | T    | Structuring idea                   | What are the tools & their uses, how to operationalize the tools? |
| (4) | Analyzing and interpreting the data | S    |                                     | How the data looks, why? |
| (5) | Calculating and thinking in computing | M&T |                                     | How the measurement techniques & the Excel program. |
| (6) | Building explanations and composing new ideas | S    |                                     | The composition of the best fish pellets. The pellet size, the best product |
| (7) | Conducting an argument from evidence | S    | Application of ideas               | How is the pellet quality? How does the fish like to eat? |
| (8) | Obtaining, evaluating, and communicating | S    | Refleksi                           | What are your efforts to keep the pellets afloat? What is the advantage of? What about entrepreneurial opportunities? |

Observation of the activity of learning implementation, the observer, provides the most appropriate answer choices in the answer column (1,2,3 or 4) for the observed component that appears. Put a mark (√) at point 4 if the Answer is True/Correct, Appropriate/Relevant, Systematic, and Coherent or Factual. Give a sign (✓) at point 3 if the Answer is True/Correct, Appropriate/Relevant, Systematic, and not Coherent or not Factual. Give a sign (✓) at point 2 if the answer is True/Correct, Appropriate/Relevant, not Systematic, and not Coherent or not Factual. Give a sign (✓) at point 1 if the answer is only one correct. Counted every aspect of each component (STEM) and calculated the score of its implementation, then calculated its average value. Each motivation is converted into interval data with a scale of four. The data obtained was changed in the form of a score, then the data in the form of the score will be changed to a score, which is the score obtained divided by the maximum score multiplied by a maximum score of 100 [1].
The data used are normalized Gain Index and classification/effectiveness to find out the increase in learning motivation [10]. The average value of normalized gain (Gain index) is the difference between the average score of the final test (post-test) divided by the difference in the results of the maximum score minus the average score of the initial test (pre-test). Interpret the normalized gain index (g) and classification [10], Table 3 as follows.

### Table 3. Index Score and Classification/effectiveness

| Normalized Gain Index | Classification          |
|-----------------------|-------------------------|
| (g) ≥ 0.70            | High/very effective     |
| 0.30 ≤ (g) ≥ 0.70     | Medium/effective        |
| (g) < 0.30            | Low/less effective      |

#### 2.2 Research procedure

The research procedure is presented in Figure 2 as follows.

**Figure 2. Constructivism-based STEM Approach Research Procedure**

#### 3. Result and Discussion

##### 3.1 Student Learning Motivation

Figure 3 and N-Gain Index (Table 4) below.

**Figure 3. Percentage of pre-test and post-test student motivation**
Table 4. N-Gain Index for each Motivation Indicator and its Classification

| Motivation       | Indeks N-Gain | Desire | Hope | Encouragement | Appreciation | Interesting | Mean |
|------------------|---------------|--------|------|---------------|--------------|--------------|------|
| Classification   |               | Effective | Effective | Effective | Effective | Effective | Effective |

Figure 3 and the details of student learning motivation in learning biotechnology material for fish pellet making through the implementation of the constructivism-based STEM approach are described as follows.

a) **Desire and Curiosity**
Based on Figure 3, the average pre-test score of students’ desire and curiosity motivation is 60, and the average post-test score is 80, with N-Gain of 0.49 (effective classification) increasing students’ desire and curiosity to learn. It is because learning is carried out contextually, teacher’s encouragement through challenges with questions, equal opportunities to express ideas, and students’ curiosity to learn new information and the availability of proper learning tools. The teacher’s efforts are through positive attitude and verbal encouragement, leading, creative, and pleasant atmosphere. It is the most crucial factor to increase student motivation [11]. [12] states that the strongest predictors of academic success include: 1) Teachers must provide positive verbal inspiration to support students’ academic independence; 2) Teachers must show positive attitudes that help motivate students; 3) Activities that are relevant to cognitive involvement in learning settings. It academically will be able to motivate students to learn.

b) **Encouragement and Needs**
The encouragement and needs of students from the average pre-test score of 65 and post-test increased to 80, with N-Gain of 0.42 (effective classification) motivating in the form of encouragement and student needs through learning the constructivism-based STEM approach. There is an encouragement to learn from students because they require skills in making fish pellets, the material is cheap or affordable, the tools and how they work are easy to apply. Following the needs and feelings of pride in the work achieved can make fish pellets useful in fish farming. Increased motivation to learn because there is a need and drive to be fulfilled [4][13].

c) **Hopes and Ideals of the Future**
The average pre-test score of 70 and post-test of 88, with N-Gain of 0.52 (effective classification) increases student hopes and ideals through the implementation of this learning because students expect the acquired skills can be utilized in life as an alternative business. Students are diligent in following learning activities and are optimistic in completing assignments because these activities are relevant to students’ needs and achievements. Increasing student motivation is an alternative form of positive impact from a more comprehensive model [14][15].

d) **Appreciation in Learning**
The average pre-test score of appreciation in learning is obtained by 60 and post-test of 70, with N-Gain of 0.37 which means that this learning gives the impression of effectively increasing the motivation of students to get an appreciation in learning. This learning allows students to participate, without any burden, and the results obtained by students are informed and complimented by students competing to produce fast and quality fish pellets to get praise from other groups and the teacher. Learning motivation also plays an important role directly affecting learning performance in learning settings. Teaching presence was found to have a direct positive impact on cognitive and social presence [3].
e) Interesting Activities in Learning

The average pre-test score of interesting in learning is obtained by 75 and the post-test increased to 86, with N-Gain of 0.44 (effective classification), increasing the student motivation in learning. Interestingly this learning is facilitated in a fun and easy to understand way. This learning, starting from orientation to reflection, is presented interestingly because the guiding questions are delivered systematically, directed, and interspersed with teacher stimulus comments with light jokes, students participate in full awareness and sincerity of themselves because of various STEM skills: skills in information processing, encouraging independent and collaborative learning [3].

From the description above, it is obtained total N-Gain index of 0.44, an effective classification of increasing student learning motivation through the constructivism-based STEM approach. This learning gives the power of guiding instructions with precise, direct, and relevant statements. Integration in its application is stated as interrelated: 1) theory with application, 2) guiding questions challenging students’ curiosity, interesting and having 3) relevant application concepts with STEM in real-life every day with 4) objectives, learning benefits according to hopes and needs student.

The learning motivation increases in learning that involve students in searching for and finding information utilizing creative collaboration and inquiry-based/problem-focused, pedagogical frameworks. It is proven to be very useful, attracting interest, increasing student desires, combined with interesting pedagogical methods, effective learning but rich experience, and involving students, learning environment, and learning attractiveness [16]. [17] state that learning based on games (interesting pedagogical methods) in STEM education is a teaching strategy that is more memorable in increasing student motivation, guiding students to foster 21st-century skills such as collaboration skills, meaningful communication skills, critical thinking skills, and creative skills as well as computational thinking.

3.2 Learning Activity

Based on the implementation of student learning activities in 4 STEM activities based on constructivism and indicators presented in Table 5 below.

| STEM Activities      | Indicators Student Learning Activities Through STEM Integration Based on Constructivism | The Score of Each Learning Activity | The Average Score of Learning Activities | Category     |
|----------------------|----------------------------------------------------------------------------------------|-------------------------------------|------------------------------------------|--------------|
|                      |                                                                                       |                                     |                                           |              |
| Science              | Answer                                                                                  | 93                                  | 86                                       | Very active  |
|                      | Respond                                                                                 | 85                                  |                                           |              |
|                      | Explain                                                                                 | 80                                  |                                           |              |
| Technology           | Determine tools and uses                                                                 | 70                                  | 65                                       | Sufficiently active |
|                      | Assemble & use tools                                                                    | 65                                  |                                           |              |
|                      | Use computing                                                                          | 60                                  |                                           |              |
| Engineering          | Design work procedure                                                                   | 65                                  | 60                                       | Sufficiently active |
|                      | Design data views                                                                       | 60                                  |                                           |              |
|                      | Design report format                                                                    | 55                                  |                                           |              |
| Mathematics          | Measure                                                                                 | 85                                  | 75                                       | Active       |
|                      | Calculate                                                                              | 80                                  |                                           |              |
|                      | Analyze data                                                                           | 60                                  |                                           |              |

Student learning activities from the implementation of learning through the integration of constructivism-based STEM approach obtained the highest average score of learning activities namely science activities (86) in very active category, technology (65) in the sufficiently active category, mathematics with a mean of 75 categorized active, and the lowest score is in the engineering activity with a score of 60 in the sufficiently active category. Science skills, related to the students’ activity of asking questions, answering, and responding, increased because if the students’ answers are wrong,
then students are not criticized by the teacher or other students. However, students are facilitated by the teacher to be able to find the answers. Learning activities facilitated by the teacher with an instruction guide challenge the participation of students sharing expertise (STEM), working together, and mutual respect.

On the other hand, the average score of engineering and technology activities is low, and it is suspected that students have no experience in designing, assembling, and using tools as students’ new experiences. The lowest student learning activity score of 55 in the less active category is designing the report format. This is due to a lack of guidance following the teacher’s statement with the method, as a challenge to the “4C” thinking skills. This is consistent with the results of the study found that the average low score is engineering and technology compared to the average score of science and mathematics [8][19]. It is considered that students have not been trained in learning that contains “4C” thinking activities [18].

Overall learning activities meet all aspects of improving the quality of learning and provide many positive impacts on the learning process, but in its implementation has its challenges including 1) Educators must have the ability or skill in using technology and require much time in developing this learning; 2) Educators must be able to build material following the method and be able to develop learning and statements in the class [19].

4. Conclusion
Based on data analysis that the constructivism-based STEM approach is effective in increasing motivation and learning activities of recycling waste into fish pellets on Biotechnology material in the extracurricular activities of SMP Purnama Pekanbaru. This study found that there are lacks in teacher activity in the suitability of instructions with the methods used in engineering activities, namely the activity of designing flowcharts, display data, and report formats.

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