The impact of STEM-based independent learning unit on students’ mastery of the respiratory system topic

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Abstract. One of the efforts to overcome distance learning problems due to the lack of facilities owned by Bali Mandara Senior High School students is by implementing Independent Learning Unit (ILU). However, the ILU that has been developed so far has not been successfully applied in the biology class as evidenced by the average value of students' understanding being four points below the passing grade. The application of STEM-based ILU is the solution in improving the students’ biology learning outcomes. In conducting the research, post-test data on biology learning outcomes on the respiratory system topic and the students' responses toward a questionnaire administered were taken from the control group and the treatment group. The average post test score was compared with the passing grade. The results showed that the percentage of the learning mastery of the experimental group using STEM-based ILU was 81% while that of the control group was 59%. It is very likely that the result occurred because STEM-based ILU provided a learning stimulus to foster the students’ independence and active involvement in competency mastery. For this reason, STEM-based ILU needs to be developed in distance learning for the other topics.

1. Introduction
Bali Mandara State Senior High School established by the Education Office of Bali Province on April 8, 2011 is a special education service school provided for students with a low economic background, that is, those from underprivileged families. Bali Mandara State Senior High School is one of the state-owned boarding schools in Bali that offer educational services using semester credit system. The semester credit system provides freedom for students in determining their learning load and learning strategies according to their learning speed, talents, and interests [1] In the learning process in the classroom, the application of the semester credit system is manifested in the Independent Learning Unit (ILU). ILU is a small unit of study and is designed sequentially from easy to difficult sequences which are designed based on the mapping of basic competencies.

Based on the Circular of the Secretary General of the Ministry of Education and Culture Number 15 of 2020 concerning the guidelines for organizing learning from home in the emergency period of the corona virus disease (Covid-19) spread, starting from March 22, 2020, SMA Negeri Bali Mandara carried out online learning. The online learning has been carried out by the teachers with the help of learning management systems such as Edmodo, Google Classroom, Quipper and Schoology. In addition, the teachers have also utilized via WhatsApp group to keep in touch with their students and the learning has been carried out in an ILU orientation. However, during the first month of implementing the online learning, two obstacles were found.
 Firstly, all students of SMA Negeri Bali Mandara come from underprivileged families. The condition of being inadequate makes them have no proper facilities to learn online. Only a few students have laptops and there are some students who still do not have smartphones. The students who do not have a smartphone or laptop must borrow from their family or closest neighbors. Not a few of the smartphone and laptop lenders provide a short period of time, thus limiting the time for the students to learn and get information from school. In addition, due to the low income of their parents, the students also have difficulty to buy internet packages, especially during this pandemic, because their parents’ income has decreased.

The second is the location of the students' homes which are scattered throughout Bali. Some students own a house located at the foot of a hill, some on the edge of a valley or in a hilly area and some even on the island of Nusa Penida—a separate one from the mainland of Bali. Such areas are difficult to reach by telephone networks, so it is also difficult to get an internet connection. This situation results in the students having to move to other areas that are reachable by the network for learning. This of course makes the students need more time just to get stronger internet signals.

Due to these two obstacles, the students were not always able to follow the learning according to the set schedule like that in the face-to-face learning. The students could only learn whenever they chanced to be allowed to borrow the needed facilities for learning from their relatives or neighbors, or whenever they got to spot with good internet connection. That is why synchronous online learning through video teleconferences could not be done then. Instead, learning using ILU could only be undergone with the help of a learning management system.

Referring to the vision of SMA Negeri Bali Mandara which is to create future leaders, graduates of the Bali Mandara Public High School are expected to have four skills that must be possessed in the industrial era 4.0. The four skills are: (1) critical thinking and problem solving, (2) communication and collaboration and (3) creative and innovative thinking. In addition, it is expected that the graduates must be literate with data, technology, and their being as humans. In addition, online learning carried out for the sake of preventing the spread of the corona virus in SMA Negeri Bali Mandara is expected to provide meaningful learning experiences for students. The four skills and expectation of providing meaningful learning experiences to students seem difficult to obtain if the distance learning carried out with ILU is approached without a combination of synchronous and unsynchronous learning.

In its practice, the ILU developed at SMA Negeri Bali Mandara has been adapted to fit the discovery learning model or the scientific approach mandated by the currently applying curriculum. However, the ILU developed in this way tended to only develop the students' understanding of the materials. Discovery is more suitable for developing understanding, while the aspects of concepts, skills, and emotions as a whole get less attention [2]. In addition, the ILU learning with the help of a learning management system had another drawback, that is, the students could not carry out experiments due to the limited infrastructure in their respective homes. This caused students' inquiry skills to be less honed. Thus, learning using ILU adapted to discovery learning had not been able to develop other aspects and did not relate to contextual conditions or real events in everyday life. This was indicated by the result of the average value of the students' understanding of the previous material which lay four points below the minimum mastery criterion (passing grade).

To overcome these problems, so as to be able to produce graduates that are expected based on the school vision and the school goal of learning during the spread of the corona disease virus, it was considered necessary to make some improvement in the on-going learning, especially under the ILU that has been illustrated in the preceding paragraphs. Based on the current literature, it is suggested that ILU can be developed based on STEM. For instance, states that the STEM approach can help teachers to show students that an integrated combination of science, technology, engineering, and mathematics concepts can be applied to develop products, systems, and processes that students can use in everyday life [3]. Furthermore, found that learning that is integrated with STEM, in addition to learning knowledge on science, technology, engineering and math concepts, also plays a role in fostering students' skills in terms of scientific investigation and problem solving [4]. Given that the STEM approach is able to develop meaningful learning when it is linked to the environment in order
to realize learning with the real world as experienced by students in their everyday it is very appropriate if a learning project carried out during the circumstances of the spread of the corona virus under the ILU framework in SMA Negeri Bali Mandara is aligned with STEM. For this reason, it was considered necessary to apply a STEM-based ILU on the topic of respiratory system in the biology class to see how it could affect the biology learning outcomes of students at SMA Negeri Bali Mandara and how the students responded to the application of the STEM-based ILU.

1.1. Research Questions
The problems to be investigated in this study are as follows.
- Can the application of STEM-based ILU on the respiratory system improve the biology learning outcomes on the respiratory system topic of students at SMA Negeri Bali Mandara?
- How is the response of students at SMA Negeri Bali Mandara regarding the application of STEM-based ILU on the respiratory system topic?

1.2. Research Objectives
The purposes of this research are to find out the following matters:
- The application of STEM-based ILU in improving the biology learning outcomes on the topic of the respiration system of students at SMA Negeri Bali Mandara.
- The response of students of SMA Negeri Bali Mandara regarding the application of STEM-based ILU on the topic of the respiratory system.

1.3. Benefits
There are two benefits to be obtained from the research conducted, namely theoretical benefits and practical benefits.

1.3.1. Theoretical benefit. The results of this study are expected to contribute to or add to the treasury of knowledge in the field of education, especially to the theories of STEM and Independent Learning as well as Distance Learning in biology instruction at high school level.

1.3.2. Practical benefits
- For Biology Teachers. This research could help improve the knowledge and skills of biology teachers in implementing ILU-assisted distance learning. In addition, the results of this study can be used as guidelines by such teachers in developing STEM-based ILU to improve their students’ biology learning outcomes.
- For the Students Involved in the Study. This research can provide to the students under the study experiences for independent learning in a distance learning situation, to foster their habit to study on their own so that they can recognize their weaknesses and strengths in learning, and to help improve their reading and writing literacy as well as their technology literacy.

2. Theoretical background

2.1. ILU
The The Independent Learning Unit (ILU) is a learning unit that contains labeling by assigning tasks and mastery of learning related to knowledge and skills that are designed in learning activity process units which are mapped according to the basic competencies, which are aligned according to the utilized textbook that is based on the curriculum applicable [5].

ILU has a number of benefits for teachers and students. The ILU benefits teachers in that they can:
1. emphasize the mastery of competencies by giving learning assignments as the context of a stimulus serving as a trigger in the initial thinking and for learning assignments in the form of Learning Dynamics Books based on one or two pairs of Basic Competencies.
2. diagnose students' learning difficulties because learning is made based on learning units, so that it can help teachers in carrying out complete learning.

3. adjust the logical sequence among Basic Competencies (BC) based on the time division of BC pairs that have similarities to the subject matters so that they can be grouped in the same ILU in a subject.

4. determine the learning load of each ILU proportionally in each subject based on the number of BCs calculated in total.

5. determine the learning load on a subject based on experiences and learning assignments demanded by each BC by considering the logical order.

6. diagnose students' learning difficulties because learning is made based on learning units, so that it can help teachers in carrying out mastery learning.

Meanwhile, students get the benefits of ILU in the sense that they can:

1. learn sequentially through ILU which is adjusted based on the speed of the their mastery based on learning-hour time unit.

2. learn independently to obtain competencies based on their speed in mastering each ILU or study independently with the textbook which is equipped with workbooks.

3. achieve a higher level of competence based on the speed or ability of their learning.

4. adjust the learning load based on their interests, talents, and learning speed or ability

Based on the guidebook for the preparation of the Independent Learning Activity Unit (ILU) by the Directorate of High School Development of the Ministry of Education and Culture, there is a systematic order in preparing ILU, which is as follows.

1. ILU title and number

2. ILU identity that consists of the name of the subject, semester, basic competence, competency achievement indicators, subject matter, time allocation, learning objectives, and learning materials

3. Concept Map

4. The learning process that consists of an introduction, general instructions for the use of ILU and core activities

5. The closing that consists of checking the thinking patterns of students, self-reflection, appreciation, and follow-up instructions

2.2. STEM-based ILU on respiratory system

The STEM stands for Science, Technology, Engineering, and Mathematics [6] which is a learning approach carried out by combining the four fields of knowledge contained in it including science, technology, engineering, and mathematics [7] by focusing on a process solving real problems in everyday life [8]. There are three things that increase when using this approach, namely 1) improving the learning process of students, 2) increasing learning opportunities for all students, and 3) developing innovative learning.

In this study, STEM was integrated in the learning process at ILU on the topic of the respiratory system. STEM-based ILU on the topic of respiration systems was previously developed using the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). This STEM approach is reflected from the process of doing a project on making a simple mask in preventing the transmission of the corona virus disease. Students were faced with real-life problems about the conditions of the lungs due to the attack from the corona virus disease in the preliminary activities, and then the concept of respiratory system was explored little by little until it ended in making a simple mask project involving science, technology, engineering and mathematics in the core activities of ILU. At the end of ILU, there were reflection, evaluation, and follow-up activities towards the learning using STEM-based ILU that had been done. The entire ILU content is shown in Appendix 7.
2.3. Biology learning outcomes

Learning outcomes are the actual abilities of students that can be measured by tests; so, the ability of students to answer or take tests is the learning result of the students concerned. Meanwhile, learning outcomes are the final formulation of the efforts made by the teacher in providing assessments to students [9].

According to [10] learning outcomes achieved by students are influenced by two main factors, namely factors from outside the students and factors that come from the students, especially their abilities. Further, detailed the two factors that influence the learning outcomes achieved by students, namely:

- Internal factors (factors from students) such as: (i) Competence and ability, (ii) ability to explore stored results, (iii) ability to succeed or show learning outcomes, (iv) ability to process learning materials, (v) ability to save learning outcomes, (vi) learning motivation and study concentration. These factors greatly affect learning outcomes.
- External factors (factors from outside students) such as: (i) the teacher as a learning coach, (ii) learning infrastructure and facilities, (iii) assessment policies, (iv) the social environment of students at school and at home, and the school curriculum [11].

Learning outcomes include three aspects, namely aspects of knowledge, skills, and attitudes. The knowledge aspect states the ability of a student in terms of knowledge of certain subjects, the skill aspect states the ability of students to be creative and work in the teaching and learning process, while the attitude aspect states the personal and social attitudes of students in their interactions during learning.

The knowledge aspect in the teaching and learning process consists of various levels. The levels are ordered by difficulty and are known as Anderson's updated Bloom taxonomy. In Anderson's updated Bloom taxonomy, these levels include knowing (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Meanwhile, the skill aspect includes observing, questioning, experimenting, associating, and creating.

Based on the explanation above, it can be concluded that learning outcomes are the results achieved by students after carrying out learning activities which are manifested in the form of numbers as a symbol of learning mastery which is strongly influenced by some external factors such as teachers and methods, and factors from within the students themselves, namely motivation, intelligence, talents, interests, and personal conditions of the learners themselves.

2.4. Related research

Several studies have stated that STEM-based teaching materials are effective in learning. STEM-based LKPD on environmental change materials can improve critical thinking skills [3]. STEM is able to provide an environment that supports the development of 21st century skills [12,13] and provides opportunities for students to apply academic knowledge in the real world [14]. STEM-based activities in the classroom can improve the quality of the learning process [15] and student learning outcomes [16-17].

On the other hand, the application of ILU can increase students' self-confidence and learning outcomes [18]. Students have high self-confidence because they feel they have mastered the material and of course, in turn, will make them confident in answering the test. STEM provides initiative and self-direction skills [19]. Initiative is meant as initiative in learning, finding solutions, while self-direction is the ability to organize oneself to do something according to a purpose. ILU is, as a matter of fact, a form of teaching material.

PjBL-based STEAM learning can improve students’ creative thinking skills [20] and students’ critical thinking skills [21]. The ability to think creatively in question consists of 1) using various techniques to get ideas, 2) creating brilliant and new ideas, 3) analyzing one's own ideas in order to improve and maximize creative efforts, 4) communicate new ideas to others effectively, 5) open and responsive to a variety of new views, 6) showing originality in working and understanding the real
world boundaries in applying new ideas, 7) seeing failure as an opportunity to learn, and 8) applying creative ideas to realize real and useful contributions to fields where innovation is applied.

Students had a positive response to learning where STEM in project-based learning posed challenges and motivated students as well as increased their activities in the classroom [20]. During the learning process, students are given the freedom to explore their own knowledge in group discussions.

2.5. Framework of thinking
On the initial conditions, the teacher had not used STEM-based ILU in distance learning so that the biology learning outcome of the students was low. In order for the learning outcomes of the biology class to increase, the teacher then used STEM-based ILU on the topic of respiratory system provided through the Edmodo learning management system to 27 students as a test class while the other 27 students assigned as a control class were not given STEM-based ILU. At the end of the lesson, the two classes were given the same test on the respiratory system the results of which were to be compared to the minimum mastery criteria.

Figure 1. Framework of thinking
3. Research method

3.1. Research design
This study was a research study using a quasi-experiential method with a post-test only nonequivalent control group design. In this method only a post test was carried out to see if there was a difference between the control class and the treatment class.

3.2. Research setting

3.2.1. Research Time. This research was conducted for 4 months from March to June. The schedule description of the research activities is shown in Table 1 below.

| No | Activities                              | Time (Month) |
|----|-----------------------------------------|--------------|
| 1  | Developing an activity plan             | March, April |
| 2  | Developing research instruments         |              |
| 3  | Doing data collection                   | May          |
| 4  | Doing data analysis                     | June         |
| 5  | Doing Discussion                        |              |
| 6  | Compiling report                        |              |

3.2.2. Research location. The research was conducted at SMAN Bali Mandara which is located at Jl. Air Sanih Kubutambahan Village, Kec. Kubutambahan Buleleng Regency which was carried out online through the WhatsApp group and Learning Management System.

3.3. Population and sample.
The population in this study were students of class XI SMAN Bali Mandara for the 2019/2020 academic year, totaling 78 students. The sample in this study was 27 students as a treatment class using STEM-based ILU and 27 students as a control class without using STEM-based ILU.

3.4. Data collection techniques and instruments

3.4.1. Data collection techniques. The data collection techniques and instruments used in this study can be seen in the following table.

| No | Type of Data                           | Data source | Instrument                                      | Time              |
|----|----------------------------------------|-------------|-------------------------------------------------|-------------------|
| 1  | Learning outcome                       | Students    | Post Test of respiratory system topics          | End of treatment  |
| 2  | Students’ response on the learning process | Students | Questionnaire                                   | End of treatment  |

3.4.2. Data collection techniques. In conducting this research, the following instruments were used: 1) written test items for post-test biology learning outcomes for the topic of the respiratory system consisting of 20 questions. Instrument questions are given in Appendix 1 and 2) questionnaire statements to obtain the students’ response data to the learning conducted. The Questionnaire can be seen in Appendix 2.
3.4.3. Validation data. Validation is required in order to obtain valid data. To obtain valid biology learning outcomes data, a grid and question analysis were made by another biology teacher. Before the questions were given to the students, the questions were tried out and tested for their validity. Based on the analysis of the validity of the questions, out of the 50 questions made, only 20 questions were proved valid. Data validation results are shown in Appendix 3. The following is the grid of questions.

Table 3. Post test blue print

| Basic Competencies | Indicator | Test Indicator | Cognitive Level | Number Question |
|--------------------|----------|----------------|-----------------|-----------------|
| 3.8 Analyzing the relationship between network structures of the composers of organs in the internal respiration system in relation with bioprocess and malfunctioning that can occur in the human respiratory system | 3.8.1 Analyzing respiratory organs in humans | Determine the organs on the breath based on the image Identify the order of organs on breathing on human | C3 | 1 |
| | 3.8.2 Analyzing the functions of the respiratory organs in humans | Determine the functions of the respiratory system organs Identify the function of the respiratory organs | C3 | 3 |
| | 3.8.3 Correlating the structure with the functions of the respiratory organs in humans | Determine the association between the functions of respiratory organs with the arrangement/structure contained in organs | C3 | 6,7,8 |
| | 3.8.4 Analyzing the respiratory mechanism of the stomach | Determine which statements are exactly related to chest breathing process Analyze the processes of chest breathing mechanism based on images Determine the mechanism of chest breathing inspiratory phase based on the chart | C3 | 9,11,12 |
| | 3.8.5 Analyzing the process of stomach respiration in humans | Analyze the mechanisms of abdominal breathing in humans based on images Determine the order of the mechanism in the respiratory phase of the stomach | C4 | 13 |
| | 3.8.6 Determining the process of exchanging O2 and CO2 in the human body | Determine the order of gas exchange with a scheme Identify the respiration process that occurs in the body Analyze internal and external breathing based on the picture | C3 | 15 |
| | 3.8.7 Predicting | Analyze diseases of the | C4 | 18,19 |
disorders and diseases that occur in the human respiratory system

respiratory organs based on the symptoms / characteristics described

Analyze diseases of the respiratory system based on an image given

The student response questionnaire consists of 5 assessment components which are described in 21 statement items. The following is a grid for student response questionnaires.

Table 4. Student response questionnaires blueprint

| Assessment Component | Item Number       | Total |
|----------------------|-------------------|-------|
| Content              | 2, 3, 4, 7, 8, 15, 18, 20 | 8     |
| Presentation         | 9, 14, 16, 17     | 4     |
| Language             | 11, 12, 13        | 3     |
| Attractiveness       | 1, 10             | 2     |
| Usefulness           | 5, 6, 19, 21      | 4     |
| Total Item           |                   | 21    |

3.5. Data analysis method

Data analysis was done by using descriptive comparative technique. Comparative descriptive analysis was done by comparing the biology learning outcomes data between the treatment class and the control class. Comparing data did not use statistics through the t-test but by comparing it with passing grade.

Student learning outcomes data were analyzed descriptively, namely by determining the value of student learning outcomes obtained through tests. The learning outcomes of students were converted on a scale of 100. The average value of learning outcomes (ALO) was calculated by the following formula.

\[
ALO = \frac{\text{The total score of students}}{\text{Number of students}}
\]  

Meanwhile, the percentage of students' learning mastery was analyzed using the following equation.

\[
NP = \frac{R}{SM}
\]  

Note:

NP = percentage Value of Students' Biology Learning Mastery
R = the number of students who received a score ≥ 76
SM = the number of students

The guidelines for the percentage of students' learning outcomes in qualitative criteria refer to the guidelines shown in the following table.
Table 5. Criteria for percentage of students' learning outcomes

| No | Criteria          | Category        |
|----|------------------|-----------------|
| 1  | 80% - 100%       | Excellent       |
| 2  | 66% - 79%        | Good            |
| 3  | 56% - 65%        | Fair            |
| 4  | 40% - 55%        | poor            |
| 5  | ≤ 40%            | very poor       |

Student response data to the use of STEM-based ILU were analyzed using the following equation.

\[
\bar{X} = \frac{\sum X}{N}
\]  

(3)

Note:
\(\bar{X}\) = the mean score of students' responses
\(\sum X\) = Total students score
\(N\) = number of students

The conversion guidelines for the average number of scores in 5 categories are shown in the following table.

Table 6. Conversion table of the average number of student response scores

| No | Criteria                           | Category          |
|----|------------------------------------|-------------------|
| 1  | \(\bar{X} \geq MI + 1,5 \text{ SDI}\) | Strongly positive |
| 2  | \(MI + 0,5 \text{ SDI} \leq \bar{X} < MI + 1,5 \text{ SDI}\) | Positive          |
| 3  | \(MI - 0,5 \text{ SDI} \leq \bar{X} < MI + 0,5 \text{ SDI}\) | Pretty positive   |
| 4  | \(MI - 1,5 \text{ SDI} \leq \bar{X} < MI - 0,5 \text{ SDI}\) | Less positive     |
| 5  | \(\bar{X} < MI - 1,5 \text{ SDI}\) | Least positive    |

Note:
\(\bar{X}\) = the mean score of students' responses
\(MI = \frac{1}{2} (\text{ideal maximum score} - \text{ideal minimum score})\)
\(\text{SDI} = \frac{1}{6} (\text{sideal maximum score} + \text{ideal minimal score})\)

Based on table 6 and the number of questions in the student response questionnaire was 21 where the maximum score for each question was 5 and the lowest score was 1. Then, the table of conversion results is shown in the following table.

Table 7. Student response score criteria

| No | Criteria  | Category         |
|----|-----------|------------------|
| 1  | \(\bar{X} \geq 73,5\) | Strongly positive |
All data analysis was carried out descriptively using the help of Microsoft Excel for Windows 2010.

4. Result and Discussion

4.1. Students’ learning outcome data

Biology learning outcomes were obtained from the end of the treatment by giving written tests through the quizizz application which consisted of 20 multiple choice questions. This learning outcome was compared with the KKM score (minimum completeness criteria) of the school, which was 76. The learning outcomes of the students in the control and treatment classes are as follows.

**Table 8. Analysis of biology learning outcomes in the control and treatment class**

| No | Class   | Number of students | Class Average Score | Quantity of students who achieved ≥ 76 | Quantity of students who achieved < 76 | Percentage of students who completed the learning | Category   |
|----|---------|--------------------|---------------------|----------------------------------------|----------------------------------------|---------------------------------------------------|------------|
| 1  | Treatment | 27                 | 88.3                | 22                                     | 5                                      | 81%                                               | Excellent  |
| 2  | Control   | 27                 | 74.5                | 16                                     | 11                                     | 59%                                               | Fair       |

![Figure 2. Comparison graphic of the completeness between treatment and control group](image)

Based on the data on biology learning outcomes, it is known that the average value of the control treatment class is 88.3 where out of the 27 students there were 22 students who completed (81%) the learning and 5 people who did not complete (19%) their learning, while the average value of the control class was 74.5 where out of the 27 students there were 16 students completed (59%) the learning and 11 people did not complete (41%) their learning.
4.2. Student response data against the use of ILU

Student responses to the use of ILU were obtained from giving a questionnaire via google form which consisted of 21 questions regarding the content, presentation, language, attractiveness and usefulness of ILU. The following are the response data of the students to the use of ILU.

**Table 9. Table of students response**

| No | Category            | Number of responses | Percentage |
|----|---------------------|---------------------|------------|
| 1  | Strongly positive   | 25                  | 92%        |
| 2  | Positive            | 1                   | 4%         |
| 3  | Pretty positive     | 1                   | 4%         |
| 4  | Less positive       | 0                   | 0%         |
| 5  | Very less positive  | 0                   | 0%         |

**Figure 3. Comparison graph of student learning outcomes in control and treatment class**

Based on the students’ response data, it was found that out of 27 students, 25 students responded very positively (92%), 1 student gave a positive response (4%) and 1 student gave a fairly positive response (4%).

4.3. Discussion

4.3.1. The application of STEM-based ILU in improving the biology learning outcomes on the topic of the respiration system of students at SMA Negeri Bali Mandara. Based on the data in table 8 about the students' learning completeness for the control class and the treatment class, it is known that the treatment class has a higher mastery value which is 81% compared to the control that has only 59% mastery value. This difference occurs because STEM-based learning activities in the classroom can improve the quality of the learning process [15]. STEM provides a learning stimulus to foster student independence and active involvement in competency mastery [22]. ILU with its systematicity can be studied step by step according to the sequence and each activity contains clear instructions so that students can learn independently or in groups. Although learning is carried out independently by students in their respective homes, learning can take place as it should, so that the quality of learning is maintained.
The STEM approach integrated in ILU made ILU more challenging by solving real problems that occurred in the environment through project completion. Thus the motivation of the students to learn increased along with their curiosity to solve problems that existed in ILU. Indirectly, STEM-based ILU became students’ learning guide to master their learning competencies independently.

STEM provides opportunities for students to apply academic knowledge in the real world. STEM-based ILU on the respiratory system material was designed so that the students were able to solve problems in their lives through a project [14]. The students felt that the knowledge they had was very meaningful in dealing with life in the real world, not just theory. This is where students found usefulness in studying biology.

In STEM-based ILU with the topic of respiration, students are asked to complete a project to make a simple mask from the problem of the covid-19 pandemic. In completing this project, students looked for information, examine the information to formulate their knowledge to decide the best mask they could make. The results of this project were communicated in writing in the form of storytelling images in ILU. Learning works effectively when students are given the opportunity to demonstrate, adapt, modify and transform new knowledge in new situations and contexts [23]. This is in line with the results of research by [18] who uncovered that STEM-based ILU provided students with experiences to develop 21st century skills. Likewise, [12] found that STEM was able to develop problem solving, communication collaboration and knowledge construction.

PjBL-based STEAM learning can improve students’ creative thinking skills [20] and students’ critical thinking skills [21]. In learning activities using STEM-based ILU, students were invited to do activities to design a project to solve a problem to produce a product from the results of this project. Learning activities carried out by these students trained their critical thinking skills in solving problems that existed in ILU. Meanwhile, the activity of designing to producing a product could shape the creativity of the students. The students could find ideas from their knowledge to be able to evaluate their own ideas to develop products from the projects they are working on.

On the other hand, the application of ILU can increase self-confidence [18] STEM-based ILU was designed so that the students learn step by step from lowest to top thinking skills. The students also began to learn from prerequisite knowledge to in-depth respiration system material. This learning activity made them confident in answering the test at the end of the topic. Thus STEM can indirectly improve student learning outcomes [16, 17].

In addition, at the end of ILU, the students reflected on their learning outcomes and could even evaluate the extent of their learning achievement. This made the students learn to understand the parts that had not been mastered on this topic and could repeat it to retain it. This is in line with the results of research by [19] which found that STEAM provides self-initiative and direction skills. Students have initiative in learning, find solutions to problems and organize themselves to do something.

4.3.2. The response of students of SMA Negeri Bali Mandara regarding the application of STEM-based ILU on the topic of the respiratory system. Based on the student response data in table 9 it is known that 92% gave very positive responses, 4% gave positive responses and 4% gave quite positive responses. This result is in line with the findings of [20] which found that students had a positive response to STEM learning. STEM-based ILU makes learning fun. This could be seen from the freedom of the students in responding to challenges to solve problems through a project. The students were free to convey their ideas in solving problems, were free to design even when making products from the projects they made. Independence was also seen from the time they carried out learning activities during their learning at home according to their abilities, so that they could determine their own learning load. This independence made the students feel comfortable to study and learning became fun.

One of the learning activities in STEM-based ILU in the topic of the respiratory system was to create a project to solve a real problem in life. Project-based activities posed challenges for the students. The students became curious whether the ideas in solving the problem were correct or not through product testing. This was what made students feel interested in learning.
STEM-based ILU systematics on the topic of respiration was designed to be attractive in presentation and designed learning activities in stages. Students felt motivated to complete learning activities step by step. When completing one learning activity they were interested in completing the next learning activity because ILU learning activities were designed to practice thinking skills in stages.

5. Conclusion

5.1. Conclusion

Based on the results of the research discussion that has been described, the following conclusions can be drawn.

1. The use of STEM-based ILU in the respiratory system material can improve students' biology learning outcomes.
2. Students have a 92% very positive response, 4% positive and 4% positive enough about the application of STEM-based ILU on the respiratory system material. The application of STEM-based ILU could improve student learning outcomes as shown by higher learning mastery compared to without STEM-based ILU. Thus, it is recommended to use STEM-based ILU, especially in distance learning.

5.2. Recommendation

Based on the research results, several suggestions can be made to improve the quality of biology learning in the future. These suggestions include the following.

1. STEM-based ILU can be developed for other biology materials or for other subjects so that it can be used as a guide in distance learning.
2. In this study, the projects undertaken by students were carried out independently because of the scattered positions of the students and the limitations of the internet network. If they had not had these obstacles, then the project could have been carried out in groups where they could have discussed with the help of several applications such as jamboard.

6. References

[1] Indra M M and Suharto L 2019 Development of independent learning activity units (ILU) for business and energy materials based on contextual learning to improve students' understanding of concepts Unnes Phy. Edu. J. 8 229-38
[2] Fadriyati 2017 A model of discovery learning based - text book of character and islamic education : an accuracy analysis of student book in elementary school J. Ta’dib 20 188-202
[3] Halim S, Andika S and Nanda A M 2019 The development of LKPD is based on a science, technology, engineering, and mathematic (STEM) approach to foster students' critical thinking skills J. Pelita Pend. 7 170-7
[4] Ulva L I 2018 The development of chemistry learning modules uses the science, technology, engineering and mathematic (STEM) approach to the material of chemical equilibrium J. Pend. Kim. 2 27-37
[5] Lisya U K 2019 The effectiveness of implementing UKBM (Independent Learning Activity Unit) in mathematics learning in Sidoarjo district Thesis Universitas Islam Negeri Sunan Ampel Surabaya
[6] Sanders M 2009 STEM, STEM education and STEM mania The Technology Teacher 68(4) 20-6
[7] Ismayani A 2016 The effect of the application of STEM project-based learning on the mathematical creativity of vocational school students Indonesian Digit. J. of Math. and Edu. 3 264–72
[8] Parta W P M 2017 The effect of the STEM (Science, Technology, Engineering, and
Mathematics) approach on the mathematics literacy of grade VIII students of SMP Negeri 5 Singaraja Thesis Universitas Pendidikan Ganesha

[9] Sudiatmika and Nurlaili L 2004 Competency-based curriculum (Jakarta: Departemen Pendidikan Nasional)

[10] Sudjana N 2005 Assessment of the teaching and learning process (Bandung: PT Remaja Rosdakarya)

[11] Dimyati and Mudjiono 2005 Learning and learning (Jakarta: Rineka Cipta)

[12] Stehle S M and Burton E E P 2019 Developing student 21st century skills in selected exemplary inclusive STEM high schools Int. J. of STEM Edu. 6:39

[13] Hadinugraningsih T et all 2017 Skills 21 and the STEAM Project in Chemistry Learning (Jakarta: LP2M UNJ)

[14] Rustaman N Y 2016 Future science learning based on STEM education Nasional Bio. Edukasi 2016 Seminar Prosiding STKIP PGRI Sumatra Barat

[15] Meyrick K M 2011 How STEM education improves student learning Meridian K-12 Schl. Comp. Tech. J. 14 1–6

[16] Wahono B, Lin, P L, and Chang, C Y 2020 Evidence of STEM enactment effectiveness in Asian student learning outcomes. Int. J. of STEM Edu. 7:36

[17] Munandar H, Lia M I and Muammar Y 2019 The use of the STEM learning model on the acid-base concept at SMAN 1 Baitusalam Lantanida J. 7 101-93

[18] Nilasari A, Efendi M M and Putri O R U 2020 Self-confidence analysis and high school mathematics learning outcomes in a unit-based curriculum for independent learning activities J. Prog. Std. Pend. Mat. 9 433-9

[19] Trilling B and Fadel C 2009 21st century skills: learning for life in our times, John Wiley & Sons, 978-0-47-055362-6.

[20] Sukmawijaya Y, Suhendar and A Juhanda 2010 The influence of the PjBL STEM learning model on students' creative thinking skills in environmental pollution material Bioeduin J. Prog. Studi Pend. Bio. 9

[21] Afifah A N, N Ilmayati and Toto 2019 STEM-based project based learning model to improve students' mastery of concepts and critical thinking skills Paper Bio-Edu National Seminar 1.

[22] Hendriana H 2014 Build students' self-confidence through humanist mathematics learning J Pengir. MIPA 19 52–60

[23] Jeong S dan Kim H 2015 The effect of a climate change monitoring program on students’ knowledge and perceptions of STEAM education in Korea. Eurasia J. of Math. Sci. & Tech. Edu. 11