The development of prototype virtual laboratory through biology, technology, engineering, and mathematics (BTEM)

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Abstract. This study aims to develop a prototype of a virtual laboratory (VL) application through Biology, Technology, Engineering, and Mathematics (BTEM) that is feasible and practical to use to facilitate virtual practicum activities on the concept of bacteria. The final product application generated from this research is expected to help students understand the concepts of bacterial. The research and development method used in this study is the Van De Akker model with four stages is Preliminary research, prototyping stage, summative evaluation, and systematic reflection and documentation stages. This research has been carried out in two phases, preliminary research and prototype stages. The next phase is implementation which will take place in the school after the covid-19 pandemic is over. Adobe Flash CS 6 and Construct 2 were used to create this application. This research has only reached the prototype development stage and limited trials by experts. The expert assessment sheet and analysis of the results of the limited trial are used as research instruments. The results showed that the prototype of the product made still needs to be improved, especially in the aspects of software engineering and visual communication design and linguistic aspects.

1. Introduction
In biology learning, practicum is the main activity developing process and inquiry skills in student [1]. Biology teachers in schools generally rarely do practicum activities for various reasons such as not having a representative laboratory, pursuing the completion of learning material, and not having time to prepare student practicum activities, even though this activity has many benefits for students. Practicums have the benefit of arousing scientific learning motivation, developing basic skills in conducting experiments, being a vehicle for learning scientific approaches, and supporting subject of matter [2]. In its implementation, according to [3] practicum activities require expensive costs and a long time so that the right solution is needed to overcome them, and computer technology offers effective and cost-effective solutions in carrying out practical activities through VL [4].

Virtual laboratory is computer programs that are used to conduct experiments through web simulations or as stand-alone applications [5]. Another definition states that VL are computer simulations that can be used by students to interact with virtual equipment and materials to conduct practicum [6]. It can be concluded that the VL is a computer simulation program that is designed like a real laboratory environment to demonstrate a concept of learning material with a specific purpose.

The results of the study [7] the use of VL show that its applications are very effective and useful in facilitating students to do practicums that are limited in their tools and materials. The use of VL has advantages such as cost savings, flexibility, multi-access, easy system configuration, minimizing maintenance, and not easily damaged [8]. VL integrated into learning scenarios are very effective in
facilitating learning in cell matter, mitosis, and cloning [9]. Research [10-13] showed that the use of VL was also able to improve the mastery of concepts, attitudes, achievements, critical thinking skills, and creative thinking of students.

Although the VL has a good level of effectiveness, [14] revealed that the use of real laboratories is still more effective than VL, but in some aspects, VL are better. Based on these studies it can be concluded that the use of VL can have a function as a complement to real laboratory activities. VL are used when practical tools and materials are too expensive or too dangerous to use [15] and are a traditional laboratory alternative [6].

According to [16] the concept of learning biology in high school which is difficult to practice directly in a laboratory is about bacteria, especially related to staining bacteria and counting bacterial colonies. This is because schools generally do not have a sufficient number of laboratory equipment for a large number of students in one practicum. Through the development of a VL based on BTEM, it can be a solution in developing basic skills of practicum in students, besides the VL developed is expected to be able to facilitate the development of BTEM and HOTS skills of students through practicum simulation activities presented.

2. Methods

This research uses Research and Development (R&D) methods [17] with four stages of development is Preliminary Research, Prototyping Stage, Summative Evaluation, and Systematic Reflection and Documentation. The next phase is implementation which will take place in the school after the covid-19 pandemic is over. VL application developed through on BTEM with the aim of integrating learning biology through the same approach as STEM, but the specific content of science is biology. The concept of bacteria was chosen as teaching material in this VL because some practicums of this concept are difficult to do directly because of constrained laboratory equipment and materials, such as practicum for making bacterial culture medium, bacterial staining, and calculation of bacterial colonies. Adobe Flash CS 6 and Construct 2 are used as applications to create VL. This research has reached the stage of developing a prototype and alpha testing by experts with expert judgment sheets used as research instruments.

3. Result and Discussion

Based on the results of research on the development of a VL through BTEM on the concept of bacteria, it was concluded that the prototype of the VL that was developed requires improvements from design aspects, hyperlinks, and crashes because the application is too large. Following are the results of the assessment of media experts and material experts on the prototype VL through BTEM on the concept of bacteria.

| No. | Indicator                      | Score | Suggestion                                                                 |
|-----|--------------------------------|-------|-----------------------------------------------------------------------------|
| 1.  | Software engineering           | 71    | (Good) The application size is too large so it needs to check the compatibility of the device being used. There is still debugging and crashing in the application |
| 2.  | Design of learning             | 80    | (Good) Learning evaluation feedback needs to be added                         |
| 3.  | Visual communication            | 70    | (Good) The background colour of the display is less attractive and seems dark. Use colours that are more suitable for composition |
Table 1. showed the prototype of a VL application based on the assessment of media experts needs to be improved in several aspects such as repairing debugging and crashes in the application as well as the appearance of the application that is less attractive because of the improper background selection. For this aspect, researchers have made improvements with the following results.

![Prototype VL Application](image1)

**Figure 1.** Design before (a) and after (b)

Figure 1 showed the appearance of a prototype VL design before and after repairing. In picture 2, the corrected results are chosen for lighter colours so the display is more attractive. The aspects of appearance and colour selection will affect the attractiveness of learning media so that it can motivate students to learn [18].

| No. | Indicator                                      | Score | Suggestion                                      |
|-----|------------------------------------------------|-------|------------------------------------------------|
| 1.  | Feasibility of the contents of teaching materials | 80    | Re-check the depth of learning material according to the applicable curriculum. |
| 2.  | Feasibility of presentation of teaching material | 78    | The BTEM aspects must be clarified again for each component |
| 3.  | Language Feasibility                           | 75    | Writing scientific terms needs to be italicized or bolded. |

Table 2 showed the aspects of the feasibility of the material presented in the VL are good. Need to be clear about the proportions of BTEM or how BTEM implementation in applications and aspects of scientific writing must follow the rules of writing that apply.

BTEM is believed to be able to integrate 21st century skills into the biology curriculum more effectively [19]. The concept of BTEM put forward by [20] essentially emphasizes on the discovery of inquiry that is integrated in BTEM. The full BTEM framework proposed [20] is as follows.
Figure 2 showed BTEM dominant activity is discovery-discovery. BTEM aims to provide a framework for teaching inquiry discovery, which emphasizes the active discovery of biological knowledge by students. Thus, students are expected to function as independent learners; and the teacher as a facilitator [20].

BTEM strongly emphasizes hands-on and mind-on activities that are self-directed to help students build their understanding of knowledge [20] [21]. In this study, the characteristics of the BTEM-based VL developed to refer to the BTEM Framework from [20] as follows.

Table 3. The BTEM components in prototype virtual laboratory

| BTEM | Explanation |
|------|-------------|
| Biology (Biology is the core content) | The learning content of bacterial concepts at the high school level includes understanding, bacterial characteristics, bacterial staining, bacterial way of life, bacterial life adjustments, reproduction, classification, roles, breeding, and countermeasures for bacterial hazards. The practicum content developed in VL is bacterial observation, culture media, bacterial staining, and counting bacterial colonies. |
| Technology (Technology utilized in the learning process) | Ability to use technology to support the learning process and biological research |
| Engineering (Engineering as a solution for problem solvers) | Finding creative problem solving solutions that are based on scientific principles |
| Mathematics (Mathematics as a computational / modelling tool) | The ability to identify, read, and communicate in the form of data generalization in the form of tables and graphs |
4. Conclusion
The prototype VL that was developed still needs improvement and further development. The aspects of software engineering and visual communication are parts that still need a lot of improvement according to the assessment by media experts. The linguistic aspect is a part that needs to be improved according to expert judgment, especially regarding the writing of scientific terms, in accordance with applicable scientific rules.

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