JPPIPA 9(4) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Food Fermentation as a Virtual Laboratory Learning Media to Empower Student's Science Process Skills

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Received: September 9, 2022
Revised: April 14, 2023
Accepted: April 25, 2023
Published: April 30, 2023

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DOI: 10.29303/jppipa.v9i4.2117

Abstract: The purposes of this research are to produce a discovery learning-based virtual laboratory learning media, to assay the feasibility of the media, and to test students' science process skills before and after the implementation of developed media. The research method used is a Research and Development (R&D) with a 4D (Four-D Model) which was modified into 3D (Define, Design, and Develop). The validation stage was carried out by a media expert, content expert, and learning expert. The instruments used include questionnaires for the analysis of student needs, interview questionnaires, validator instruments, student responses, teacher responses, and pretest-posttest. The data collection technique was carried out by distributing student and teacher response questionnaires after learning. Science process skills are measured using a pretest-posttest. The virtual-laboratory learning media can be operated on android and personal computers (PC). The validation results showed that the multimedia was very feasible with a percentage of 92.7%, meanwhile, the material, and evaluation validation were considered feasible, with a percentage of 85.1% and 83.02% respectively. There were differences in students' science process skills before and after the implementation of discovery learning-based virtual laboratory learning media shown by the results of the paired t-test, namely the Sig value (2-tailed) 0.000<0.05.

Keywords: Conventional biotechnology; Discovery learning 4D; Science process skills; Virtual laboratory

Introduction

The 2013 curriculum emphasizes the application of a scientific approach in the learning process. According to Zeidan & Jayosi, (2014) the learning process of learners must combine skills, knowledge, and attitudes. Nuzulia et al (2017) states that through science process skills, the scientific approach to science learning can be applied. Science process skills are necessary tools for generating and using scientific information, conducting scientific research, and solving problems. Science process skills are very important to be empowered `due to the improvement of problem-solving skills and rational thinking skills for learners. Science process skills can be empowered with practicum method (Wiwin & Kustijono, 2018). This is because practicum develops psychomotor skills and cognitive and affective skills.

The development of technology is more sophisticated, for example, a practicum designed with ICT is called a virtual laboratory (Reeves & Crippen, 2021). The use of virtual laboratories is increasing, especially in learning during the pandemic, where the interaction between teachers and students in the classroom is limited, and it is not possible to do a practicum in the laboratory (Kapilan, et al. 2021). The use of a virtual laboratory has various benefits in learning, namely minimizing time constraints, reducing geographical barriers and economic barriers, improving the quality of experiments, increasing learning effectiveness, and improving security and safety because it does not interact with real tools and materials (Ferreira, 2012). Virtual laboratory laboratories are also more economical compared to conventional laboratories, due to limited equipment, laboratory assistants, maintenance, and operating cost associated with the conventional laboratory (Sasongko & Widiastuti, 2019). To be more effective I n virtual laboratory implementation in the learning process, a discovery learning model is applied. Discovery learning is one of the learning models suggested in the 2013

How to Cite:
Nisa, W.M., Fatmawati, U., & Santosa, S. (2023). Food Fermentation as a Virtual Laboratory Learning Media to Empower Student's Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2296–2304. https://doi.org/10.29303/jppipa.v9i4.2117

curriculum where this curriculum emphasizes a scientific approach and competence. Learning by implementing a virtual laboratory using the discovery learning model provides opportunities for students to gain experience and conduct experiments in finding their learning concepts (Sari, et al. 2017), increase student learning outcome (Minarni et al., 2022), and can gain conceptual knowledge and develop science process skills (Khairudin et, al. 2019; Manikowati & Iskandar, 2018).

Food fermentation is included in the study of biotechnology which is one of the teaching materials in the subject of Biology class XII in the second semester. According to its development, biotechnology is divided into two types, namely conventional biotechnology, and modern biotechnology (R. A. Safitri et al., 2021). Food fermentation materials belonging to conventional biotechnology. Fermentation topics are still very difficult for learners to understand. Based on the preliminary study, it is known that the availability of tools and materials and the use of biological laboratories are external factors that cause learning difficulties. Internal factors causing learning difficulties consist of factors of interest, aptitude, and motivation (Rahmadani, et al. 2017).

One of the practicums carried out on conventional biotechnology tpoic is to make fermented products. Fermentation practicum in high school requires students to produce fermentative food, so that the students gain the theory and knowledge of the fermentation process. Students only do practicum to produce one product due to time and cost constraints. This is supported by the statement of Holzapfel, (2002) that the natural fermentation process takes a relatively long time and the risk of failure is high.

The preference for suitable learning media is one of the important things to determine learning success. One of the media that can be used to facilitate learning on biotechnology material is a virtual laboratory. The fermentation practicum process to produce examples of conventional biotechnology products generally requires a relatively long time and is prone to failure, this can be overcome by using one of the learning media, namely the virtual laboratory. The use of a virtual laboratory allows students to conduct experiments repeatedly and be flexible to do it anywhere. Potkonjak et al. (2016) state that virtual laboratories are not considered replacements or competitors to real laboratories, but rather focus on new opportunities that are not realized in real laboratories at an affordable cost.

The development of via virtual laboratory on the fermentation process which empowers the student's science process skills in high school was not much developed, so this research conducted the development of a virtual laboratory to enhance the student' science process skills.

Method

The type of research used is a Research and Development (R&D) method which aims to develop learning media in the form of a virtual laboratory based on discovery learning on food fermentation in the biotechnology concept of class XII SMA. The development of media refers to Thiagarajan theory with a 4D development design (Four-D Model) (Figure 1) modified to 3D referring Hodiyanto et al. (2020) this is because the research is carried out by students with limited facilities, time, materials as and costs. The stages were only implemented until the development stage, the development of learning media developed already includes the principle of development research Arkadiantika et al. (2020). The 3D research stage consists of the definition, design, and development (Thiagarajan, 1976).

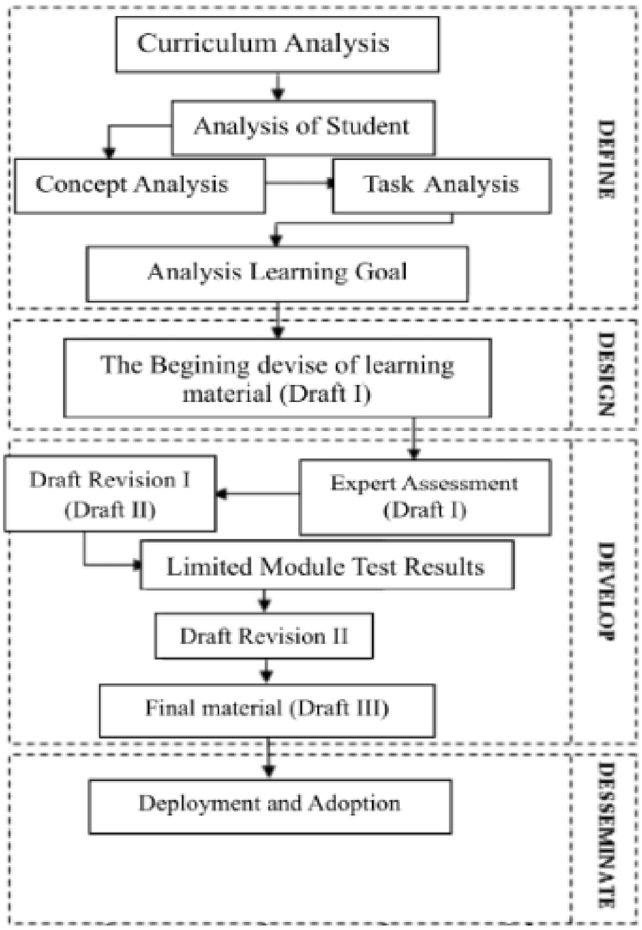

Figure 1. Model 4-D by Thiagarajan (Fitrayati et al. 2016).

Define includes several 5 steps, namely (1) Curriculum Analysis, aiming to determine the basic problems faced in curriculum learning Biology class XII. This stage was conducted interviews with the teachers and observations of the laboratory facility; (2) Students Analysis, to get an overview of the characteristics of learners, level of knowledge, skills, and learning styles of learners; (3) Concept Analysis, to choose the concept or material presented in the development product. At this stage, identification of the material is carried out through teacher and student interviews; (4) Task Analysis, to find out the tasks and abilities that must be achieved by students by the biotechnology material of class XII SMA; (5) Specifying learning goals, to find out the learning objectives to be achieved after carrying out the teaching and learning process (Fitrayati, et al. 2016).

The second stage, namely design, consists of (1) Media selection, to find out the media that best suits the characteristics of the selected material and the needs of students, adjust the results of the front-end analysis, student analysis, concept analysis, task analysis, and goal analysis; (2) Format selection, to select ted format is by the format needed in the virtual laboratory application; (3) Initial design, the initial design is a design that has been made by researchers, namely the virtual storyboard laboratory. The storyboard is a summary of the lab's virtual narrative to be created (Mahesti et al., 2023).

The last is development, consisting of (1) Expert validation, Expert validation is a technique to get advice and material improvements from experts. Several experts were asked to evaluate the learning tools. This is so that the material and media created can be more effective, useful, and of high quality; (2) Limited trials, to obtain direct input from learners on virtual laboratory-based discovery learning; (3) Field trials, conducted with a greater number of learners. Field trials were conducted to determine the use of virtual labs in learning, differences in science process skills scores, and input and criticism from field trial students (Aryuntini et al., 2018).

The subjects of this study were taken by purposive sampling technique. Purposive sampling uses the criteria chosen by the researcher so that the sample taken is a sample that meets the criteria set based on the aims of the research (Lenaini, 2021). The criteria chosen are students who have studied biotechnology, have an Android or Laptop that can access the internet, and the availability of participating in research. The population of this sample is students of class XII MIPA MAN 1 Pati, Central Java. The number of samples is taken based on the Slovin formula by 10%. The research subjects will be divided into 2 groups, namely limited trials and field trials. A limited was taken by 20 learners referring to the research (Safitri, 2018). Field trials were taken by 73 learners the calculation of the Slovin formula (Asra and Prasetyo 2015).

Data analysis techniques in this study are descriptive quantitative and qualitative analysis. Quantitative data was obtained through the results of student analysis questionnaires, pretest, and post-test questions, and validator assessments. Qualitative data were obtained from the results of interviews and suggestions given by validators and learners. The calculation of the results of the student analysis questionnaire, pretest, and post-test questions and validators can use the calculation formula below:

$$\text{Result} = \frac{total\ score\ gained}{Maximum\ score}\ x\ 100\% \quad (1)$$

The feasibility assessment results are converted into qualitative data descriptions according to the media feasibility criteria presented in table 1.

Table 1. Feasilbility Criteria

Percentage (%)	Criteria	Conclusion
85-100	Very Feasible	Products can be use without revision
69-84	Feasible	Products can be use with minor revision
53-68	Quite Feasible	Products can be use with many revision
37-52	Less Feasible	Producte still need intensive consultation

(Sadikin et al, 2020)

Science Process Skills data were collected in the form of pretests and posttest and s analyzed using paired t-tests to determine if there was a significant difference between the initial and the final students' science process skills. The prerequisite tests for paired T-tests are normality and homogeneity tests.

Previously, a hypothesis was made first:

H0 : There is no significant difference in the use of virtual learning media laboratories to empower students' science process skills

H1 : There are significant differences in the use of virtual learning media laboratories to empower students' science process skills

The basics of decision-making in the paired sample t-test according to Santoso, (2014), are As follows:

If the value *Sig. (2-tailed)* < 0.05, then H_0 is rejected and H_1 Accepted

If the values *Sig. (2-tailed)*>0.05, then H_0 accepted and H_1 rejected

Result and Discussion

Development of virtual laboratory

The result of this Research and Development research is a virtual laboratory learning media. Media can be used by teachers and students to understand the material and to carry out food fermentation practicum which was included in conventional biotechnology materials. The development process goes through several stages, namely define, design, and develop.

Define

This stage consists of 5 steps starting with curriculum analysis, which identifies the curriculum obstacles faced by teachers and students in learning. Based on the interviews, teachers stated that there were obstacles in learning, especially during online learning caused by Covid-19, which makes it difficult for teachers to know whether students already understand what is explained or not. Moreover, the teachers who are accustomed to carrying out face-to-face learning also meet several obstacles in learning such as unpreparedness in teaching due to the change in the learning system from offline to online learning, therefore the teachers should understand the learning technology (Sholichin, et al. 2020). Another obstacle in conducting practicum was the inadequate facility of the laboratory such as the equipment that were not provided and sufficient for students. According to student's interview, sometimes they felt bored during learning, especially when online class, besides that the internet connection was not always stable. Consequently, the interesting learning media which can promote practicum activities are needed, so a virtual laboratory learning media is chosen to be developed.

The next stage was carried out an analysis of concepts, tasks, and goals. Based on the interviews with biology teachers, conventional biotechnology sub-materials especially food fermentation were selected as sub-materials that will be presented in the virtual laboratory. Task and objective was adjusted to the selected basic competencies, namely, KD 3.10 analyzes the principles of Biotechnology and its application as an effort to improve human welfare and KD 4.10 presents reports on the results of experiments on the application of conventional Biotechnology principles based on scientific methods.

Design

A virtual laboratory is an application that can be used in android (.apk format) and personal computer (PC) (.exe format) (Muhajarah & Sulthon, 2020). Media creation uses coral drawing to create the design, visual studio, and unity.

The initial design was made according to the storyboard and flowchart that had been made before. The virtual laboratory was presented with components of conventional biotechnology materials, fermentation practicum instructions, trials, or practicum consisting of lactic acid fermentation, acetic acid, alcohol, and fungi. The virtual media laboratory was made in the following design (Figure 2):

Figure 2. Home Page

The front page showed the appearance of opening the virtual laboratory application, it contains the name of the application and materials presented at the virtual laboratory, the identity of the student and supervisor, and the start button to start practicum activities or enter the menu page

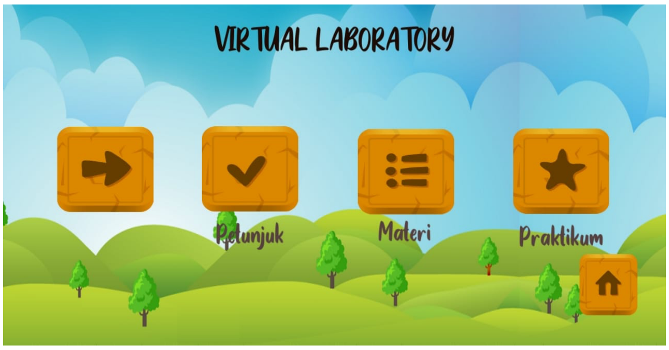

Figure 3. Menu Page

After students click the start button that is presented on the front page, the next display is the menu page (Figure 3). This page consists of a practicum destination button, a hint button, a material button, a practicum button

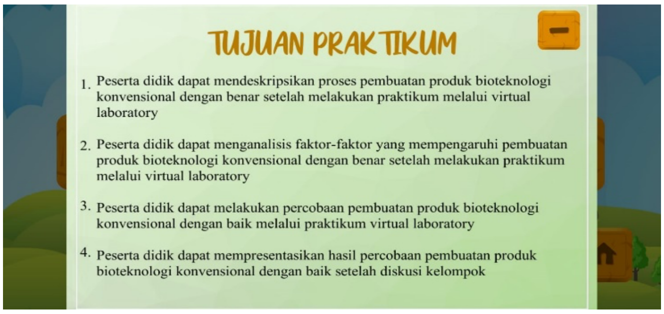

Figure 4. Practicum Purpose Page

The learning objectives page (Figure 4) contains learning objectives that formulated from the indicators. The bottom page comes with a back button to return to the menu page

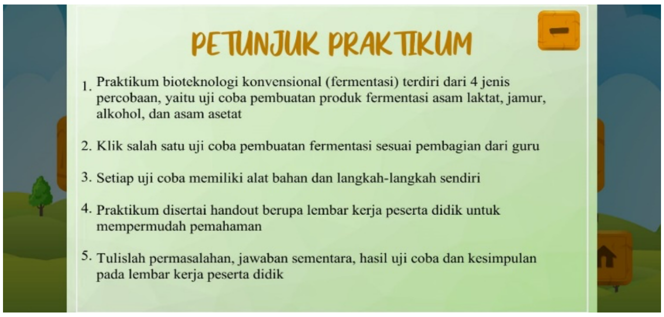

Figure 5. Practicum Instruction Page

The practicum instructions page (Figure 5) contains general instructions on how to use the virtual laboratory. The hint page comes with a back button to return to the menu page.

Figure 6. Material Page

The material page (Figure 6) in the virtual media laboratory consists of several discussion points, namely the understanding of conventional biotechnology, the benefits of conventional biotechnology, and fermentation consisting of lactic acid fermentation, mold, alcohol, and acetic acid.

Figure 7. Practicum Page

The practicum page (Figure 7) contains a problem-based, a temporary answer, and a start practicum button. The problem presented several questions where students were asked to identify the answers by discussing with their group. The temporary answer button serves the information for so students that they can write the answers on the students worksheet. The start practicum button contains several practicum options such as lactic acid fermentation, mold fermentation, alcohol, and acetic acid fermentation.

Figure 8. Yogurt Practicum Page

Figure 8. a contains lactic acid fermentation practicum in making yogurt. The components in this page are the tools and materials used for the yogurt-making practicum, the process of making yogurt based on the temperature difference in incubation, the addition of bacterial starter, and the preparation of milk.

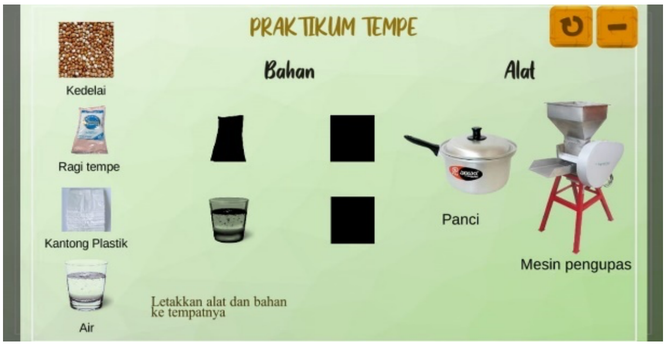

Figure 9. Tempe Practicum Page

Figur 9 contains about mold practicum, namely on tempeh products. Ton components in this page are the tools and materials used for the tempeh making, the tempeh manufacturing process based on the preparation of soybean, inoculation of fungal starter (*Rhizopus* sp.), and fermentation.

Figure 10. Tape Practicum Page

Figure 10. contains alcohol practicum, especially in making cassava tape products. Ton components in this

page are the tools and materials used for tape making practicum, the tape-making process based on the material preparation, inoculum addition, and fermentation.

Figure 11. Nata de coco Practicum Page

Figure 11. contains the practicum of acetic acid of nata de coco production. The components in this page are the tools and materials used for the practicum of making nata de coco, the preparation of coconut water, the bacterial starter inoculation, and the process of making nata de coco.

Develop

The virtual laboratory that has been created, were validated by experts using a questionnaire with a Likert scale of 1 to 4. Validation was carried out on media, material, Lesson Plan, and evaluation instruments. The validation results can be seen in table 2.

Table 2. Validation Results by Experts

Expert Validation	Percentage (%)	Category
Media	92.7	Very Feasible
Material	85.1	Very Feasible
Lesson Plan	85.4	Very Feasible
Pretest Posttest	91.7	Very Feasible

Based on Table 2, the results of the media validation was 92.7%, material experts validation was 85.1%, learning experts validation was 85.4%, and evaluation instrument for pretest and posttest was 91.7%. Based on the data, it can be concluded that the validation results were included in the very feasible category by the criteria from Sadikin, et al. (2020) so that it can be applied with revisions.

The revised media were then tested on a limited and field trial. The limited trial was carried out first with 20 students to obtain the suggestions and media improvement, then the revision was carried out based on the comments and suggestions from the first trial. In second trial was conducted with 73 students in XII MIPA class of MAN 1 Pati, Central Java. The limited trial and field stages were carried out by introducing a virtual laboratory that has been developed then practice using their gadgets. After the students finished the practicum trial using a virtual laboratory, they were asked to fill out a response questionnaire to provide feedback and suggestions. The results of the limited trial response and the field can be seen in table 3.

Table 3. Learner Responses

Learner response	Persentage (%)	Category
Limited trial	83.0	Very feasible
Field trials	87.51	Very feasible

The results of the media first trial was 83.02% and the field trial was 87.51%. According to the media eligibility, 83.02% and 87.51% were very feasible categories. Based on the results of this limited trial, the virtual laboratory learning media is very feasible to use field trials with revisions according to student suggestions and comments.

Student's Science Process Skills after Virtual Laboratory Implementation

Science process skills were measured using pretest and posttest questions consisting of 6 aspects of science process skills. Pretest questions were distributed to students before the application of virtual laboratory learning media in conventional biotechnology materials and post-test questions are given after learning. One of the objectives of this study was to empower the science process skills of learners. Pretest and post-test results based on 6 aspects of science process skills (Table 4).

Table 4. Pretest and Posttest Results

Science Process Skills Aspects	Pretest (%)	Postest (%)
Plan an experiment	75.7	89.4
Hypothesis	29.5	64.7
Observation	64.0	89.4
Applying the Concept	59.9	72.6
Communicate	47.9	75.0
Interpretation	64.7	84.9

The results showed that in the pretest and post-test, the hypothesis aspect had the lowest percentage, namely 29.5% in the pretest and 64.7% in the post-test. This is due to most of the students did not answer the questions correctly, many students answer perfunctorily and even many do not answer at all. After analyzing each student's answer, it turned out that many did not understand what is meant by a hypothesis, as well as free variables, bound variables, and control variables. Mahmudah, et al. (2019) state that the hypothesizing of students is still in the low category. The ability to hypothesize or predict is complex. To be able to predict, it is necessary to have the ability to analyze, interpret data and explain causal relationships (Dewi & Nugroho, 2015).

The highest percentage in both pretest and posttest was obtained by planning experiments with a percentage of 75.7% in the pretest and 89.4% in the post-test. There was a discrepancy when the percentage of planning experiments is better than hypothesizing. If in the hypothetical aspect the learner's answer is less complete, it will affect their ability to design the experiment. After the analysis, it turned out that students had obstacles in making hypotheses, but students simply understood the experiment such as what tools and materials must be prepared and how the experiment work. Therefore, even though the hypothesis aspect was low, students could still answer questions on the aspect of planning the experiment.

After the normality test and homogeneity test on the gained data, a paired T-test was carried out. Based on the results of the paired T-test, Sig results were obtained. (2-tailed) is 0.000 < 0.05, then H0 is rejected and H1 is accepted. So the conclusion can be drawn that there was a significant difference in students' science process skills after using the virtual media laboratory. This result in line with the research by Usman, et al. (2021) that the use of virtual laboratory learning media was efficiently used in science learning to improve students' science process skills in carrying out experiments. Swandi et al., (2014) states that learning by applying virtual media laboratory provides opportunities for students to explore, thus allowing them to always be active instead of just listening to material explanations by teachers.

Conclusion

Based on the results of research and data analysis, it can be concluded that the virtual laboratory can be developed by referring to a 4D research model modified to 3D (define, design, develop). The virtual laboratory developed was very feasible to be applied based on the validation results by experts with a score of 92.7% for media validation, 85.1% for material validation, 85.4% for lesson plan validation, and 91.7% validation of pretest and posttest questions. The media trial showed a very decent category with a score of 83.02% in the limited trial and 87.51% in the field trial. There was a significant difference in the science process skills of students before and after the implementation of the discovery learning-based virtual laboratory learning media, indicated by the difference in the average pretest posttest scores of 22.37 and the paired sample t-test results obtained Sig (2 tailed) value results of 0.000 < 0.0.

Acknowledgments

Thanks to the pricipal of MAN 1 Pati for granting permission so that researchers can complete the research. Thank you to Mr. Febri Liantoni, S.ST., M.Kom, who has been willing to be a media expert validation. Thank you to Mrs. Dr. Sri Martina Wiraswati, M.Si, who has been willing to material expert validation. Thank you Mrs. Daniar Setyo Rini, S.Pd., M.Pd, who has been willing to be a validation learning expert.

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