



Validity and Effectiveness of STEAM-Based Food Microbiology Electronic Booklet to Improve Critical Thinking Skills of Biology Students

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ABSTRACT

Objective: This research and development aims to determine the validity and effectiveness of STEAM-based food microbiology electronic booklets based on the assessment of validators and the results of student critical thinking skills tests. **Method:** This research is an R&D study using the ADDIE development model. The developed product was tested on students using the One Group Pretest-Posttest research design. The validity test was carried out by giving a questionnaire to the validator, and the effectiveness test was carried out by giving a test in the form of 20 fill-in questions to 15 Biology students. **Results:** The results of this study are that STEAM-based electronic booklets are very feasible to use as teaching materials and learning media and are effective in teaching food microbiology because they can improve students' critical thinking skills. This study is recommended to carry out STEAM-based electronic booklet development innovations in other food microbiology materials. **Novelty:** The novelty of this study lies in the research variables, which focus on the validity and effectiveness of food microbiology electronic booklets integrated with the STEAM approach to obtain teaching materials that encourage students to be active in learning activities.

INTRODUCTION

Food microbiology is one of the elective courses in the Biology Study Program at Medan State University. Food microbiology is a branch of microbiology that discusses microorganisms' beneficial and harmful roles (Hasruddin & Husna, 2022). The findings of problems in learning food microbiology from the questionnaire distribution students are as follows: 1) The learning process is passive, and students are only given assignments. 2) Learning resources and learning media used are PowerPoint slides that contain only concepts. 3) Information obtained only uses books containing concepts with lengthy explanations, and evaluation questions are only short fill-in questions. 4) The preliminary test results showed that the learner's critical thinking skills were still low, with an average score of 63.6.

All microbiology studies are closely related to everyday life, so critical thinking skills and abilities are needed. Critical thinking is a high-level thinking skill that requires pupils to use their knowledge levels to analyze, evaluate, and create (Permana et al., 2019). Critical thinking skills are concerned with determining answers, planning tactics, scientific procedures, and solving problems to obtain answers (Bustami et al., 2019; Zulfaneti et al., 2018). Currently, many studies have revealed that the critical thinking skills of pupils in Indonesia are comparatively low; this is supported by research results from the Program for International Student Assessment (PISA) (Magdalena et al., 2020). For this reason, it is necessary to make systematic efforts to improve these critical thinking skills especially (Wati & Anggraini, 2019).

Referring to the difficulties and problems above, the limited teaching materials and passive lecturing have resulted in pupils' low critical thinking skills. Thus, it is necessary to develop teaching materials or supporting teaching media that can enhance pupils' critical thinking (Alsaleh, 2020; Lestari et al., 2021; Popova & Jones, 2021; Saphira et al., 2023; Zou'bi, 2021). Some literature mentions that efforts to improve students' critical thinking include using varied learning strategies as well as utilizing technology during learning activities, such as multimedia and electronic books (Fajarianingtyas et al., 2023; Hidayati et al., 2019; Sastradewi, 2022). However, media use does not necessarily improve pupils' critical thinking skills. Besides using media, there also needs to be a teaching method that can encourage pupils to think more critically (Islami & Soekamto, 2022). One approach capable of improving critical thinking is the STEAM method.

STEAM is one of the teaching methods that provide opportunities for pupils to build skills in the natural and social sciences, as well as enhance the skills needed for the 21st century, such as language skills and critical thinking (Marshel & Ratnawulan, 2020; Redhana, 2019; Rohmah & Prahani, 2021; Saphira et al., 2022), creative thinking, and other skills (Zubaidah, 2019). The findings align with Hasruddin and Lestari (2020), who state that applying STEAM during teaching and learning activities can improve skills in higher-level thinking and student creativity. Based on this, researchers need to describe some research results that develop food microbiology teaching materials and use the STEAM approach in learning. Research by Harun et al. (2023) states that the development books of food microbiology are effective in helping to upgrade pupils' critical thinking skills. Furthermore, Jiyaunnajah et al. (2023) state that e-booklets are very feasible to use as teaching materials for the immune system and get good feedback from their pupils.

Another study by Fiqriani et al. (2023) stated that e-booklets are very valid for enrichment materials for the concept of Animalia in high school. In line with Sinaga et al. (2023), e-booklets are feasible for learning media and raise pupils' education outcomes on Biodiversity material. A study by Vebianawati et al. (2023) states that biodiversity booklets are very valid for use as learning media. Then, research by Hoiroh & Isnawati (2020) states that e-booklets can improve critical thinking skills because e-booklets contain specific information, unique designs, and images that support the explanation of the contents of e-booklets so that students easily understand them. STEAM-based electronic teaching materials can upgrade HOTS (Sari & Sutihat, 2022).

The novelty of this research can be seen from the fundamental differences with previous studies, where the variables used in this study focus on the validity and effectiveness of food microbiology electronic booklets integrated with the STEAM approach. The research questions obtained based on the description above are: (1) How is the validity of the STEAM-based food microbiology electronic booklet based on expert assessment? (2) How is the effectiveness of STEAM-based food microbiology electronic booklets on pupils' critical thinking about pretest and posttest results?

Based on these research questions, the objectives of the research are to establish the validity of STEAM-based food microbiology e-booklets based on the evaluation of material masters, learning design masters, and layout masters. This study also intends to look at the effectiveness of STEAM-based food microbiology e-booklets in relation to pupils' critical thinking pretest and posttest scores.

RESEARCH METHOD

The type used in this research is R&D, which uses ADDIE for analysis, design, development, implementation, and evaluation. The flow of research implementation can be seen in Figure 1.

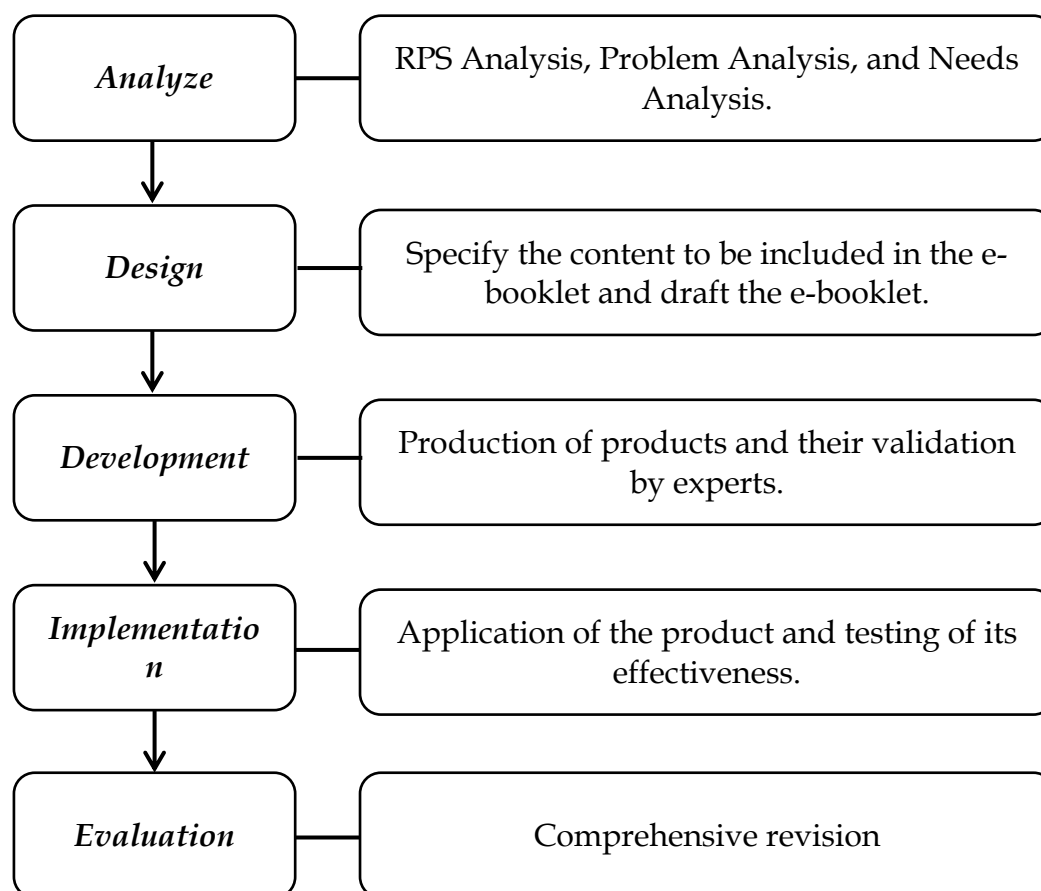


Figure 1. Chart of booklet electronic research and development procedures.

The product trial design in development research aims to perfect and implement the product directly in the field. The trial design was carried out using One Group Pretest-Posttest. In this design, there is one group or class, namely the class that will be used for experiments without a control class. The research was conducted on Biology students of the Faculty of Mathematics and Natural Sciences UNIMED Batch 2021, totaling 15 people. The measuring instruments used during the trial were tests and questionnaires. The test uses 20 description questions to measure the extent of changes in students' critical thinking test scores shortly and after using the STEAM-based food microbiology e-booklet. A non-test in the form of a questionnaire is given to validators to measure the validity of the product.

Data analysis was carried out based on Likert scale calculation scores, namely: Very good (Score 4), Good (Score 3), Less Good (Score 2), and Very Poor (Score 1). Then, the product's validity was calculated based on the average use formula from Riduwan (2013). The validity test was carried out regarding the validity of the material, learning design, and layout. The validity assessment is presented in Table 1.

Table 1. Product validity interpretation.

| Percentage | Validity criteria |
|------------|-------------------|
| 81% - 100% | Very valid |
| 61% - 80% | Valid |
| 41% - 60% | Less valid |
| ≤ 40% | Invalid |

Electronic booklets, pretests, and post-tests were conducted to determine the effectiveness of STEAM-based food microbiology. The pretest and posttest data were processed using SPSS v.22 for t-testing and calculating N-Gain to determine the increase in pupils' critical thinking skills immediately and after using the e-booklet. The results of the N-Gain calculation are in Table 2.

Table 2. Categories of interpretation of n-gain calculation.

| Percentage | Category |
|---------------|-----------------|
| < 40.0% | Ineffective |
| 40.0% – 55.0% | Less effective |
| 56.0 – 75.0% | Quite effective |
| > 76.0% | Effective |

RESULTS AND DISCUSSION

Results

One of the ADDIE stages is Development, which is the initial design, which is then validated by the validator. The initial design results are presented in Figure 2.

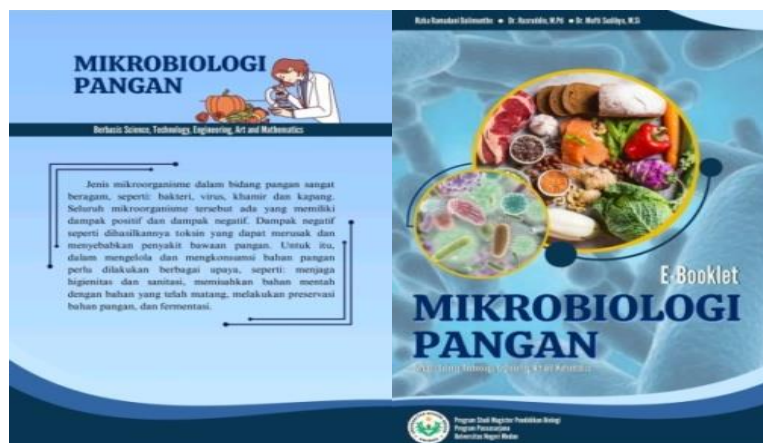


Figure 2. The initial view of the STEAM-based food microbiology booklet electronic.

The initial design was then validated to measure the validity of the STEAM-based food microbiology electronic booklet. Table 4 shows the results of product validity based on material experts.

Table 3. Material expert assessment results.

| No | Assessed aspect | Validator | |
|----|----------------------|-----------|-----------|
| | | Expert I | Expert II |
| 1 | Material suitability | 83% | 75% |
| 2 | Material accuracy | 83% | 67% |
| 3 | Material sequence | 88% | 75% |
| 4 | STEAM components | 75% | 85% |
| | Average | 82% | 76% |
| | Category | Valid | |

The data in Table 3 confirm that the developed product is suitable for use during teaching activities, with an average percentage of expert I 82% and expert II 76%. Then, to measure the suitability of the STEAM components with the material, a learning design expert carried out a validity test. The results obtained are in Table 4.

Table 4. Learning design expert assessment results.

| No | Assessed aspect | Validator | |
|----|------------------------------|------------|-----------|
| | | Expert I | Expert II |
| 1 | Presentation technique | 100% | 100% |
| 2 | Learning presentation | 92% | 100% |
| 3 | STEAM learning | 90% | 65% |
| 4 | Completeness of presentation | 100% | 100% |
| | Average | 96% | 91% |
| | Category | Very Valid | |

The data in Table 4 showed that the average percentage of Expert I was 96%, while from Expert II, it was 91%, so the product was very valid. Then, to measure whether the e-booklet display was appropriate, a layout expert carried out a validity test., the results of which are in Table 5.

Table 5. Layout expert assessment results.

| No | Assessed aspect | Validator | |
|----|-------------------------|------------|-----------|
| | | Expert I | Expert II |
| 1 | Cover design | 94% | 94% |
| 2 | Cover typography | 94% | 81% |
| 3 | Content design | 91% | 84% |
| 4 | Illustration of content | 100% | 100% |
| | Average | 95% | 90% |
| | Category | Very Valid | |

The results written in Table 5 show that the average percentage obtained from Layout Expert I is 95%, and Layout Expert II is 90%. It is known that the STEAM-based food microbiology electronic booklet is very valid in terms of its layout. A comparison of the average percentage results from the validator's assessment of the material, learning design, and layout aspects can be seen in Figure 3

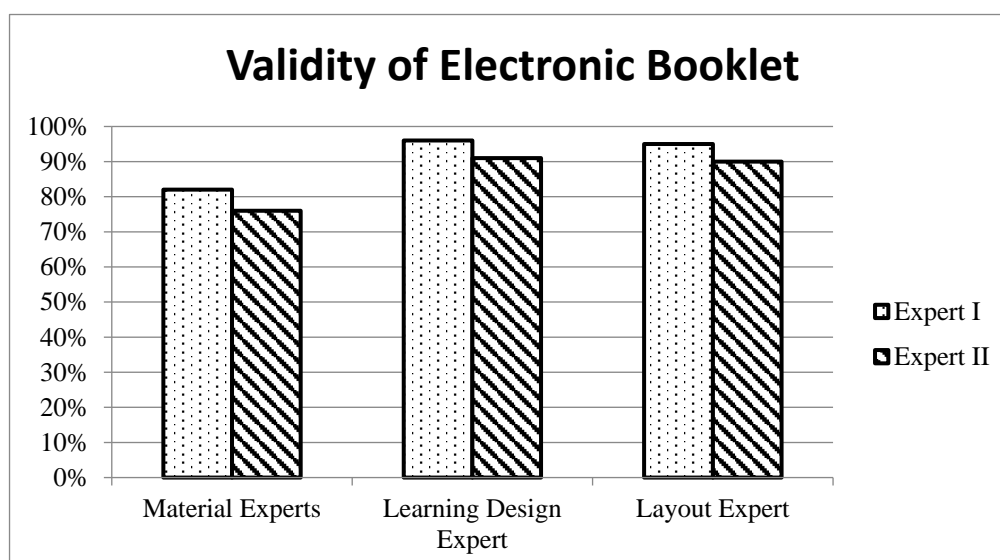


Figure 3. Comparison of assessment results by validators on each aspect.

During the validity test, suggestions were also obtained from experts as material to improve the products that had been developed. A summary of revisions from validators can be seen in Table 6.

Table 6. Summary of suggestions from validators and follow-up on suggestions.

| Validator | Feedback and Review | Action |
|------------------------|---|--------|
| Material expert | 1. We need to separate types of food, namely animal and plant-based food. | Fixed |
| | 2. We need to add material to the mechanism of damage to food. | |
| | 3. We need to add examples of food products and microbiological product handling that are relevant to life today. | |
| Learning design expert | 1. Add videos related to material in the form of procedures to make it more interactive. | Fixed |
| | 2. Need to clarify the suitability of some STEAM components with the material. | |
| Layout expert | 1. Need to add arrows to the discussion of procedures. | Fixed |
| | 2. Need to separate the sub-chapters so that they are not too tight. | |
| | 3. Need to change the A5 paper size to A4 because it is electronic. | |
| | 4. We need to change the font and improve the color contrast. | |
| | 5. We need to add learning videos. | |
| | 6. I need to change the spacing to 1.15. | |

After the electronic booklet is validated and declared feasible, the product is tested on students to determine the effectiveness of the food microbiology e-booklet. The data of students' pretest and posttest scores by completing 20 descriptive questions were used for the effectiveness test. The results obtained are presented in Table 7.

Table 7. Student pretest and posttest results.

| Student Learning Outcomes | Overall Score | Average Score |
|---------------------------|---------------|---------------|
| Pretest | 739 | 49.27 |
| Posttest | 1142 | 76.13 |

After acquiring pretest and post-test data, a t-test was conducted using SPSS version 22 software to determine whether student scores were comparable immediately and after use, namely the use of STEAM-based food microbiology electronic booklets. The t-test results can be seen in Table 8.

Table 8. T-test results.

| Student Learning Outcomes | t Count | Sig. (2-tailed) | Conclusion |
|---------------------------|---------|-----------------|------------------------|
| Pretest-Posttest | -21.695 | 0.000 | Significant difference |

The t-test results show that the significance value of the pretest and post-test is 0.000 <0.05. It can be concluded that there is a significant difference in students' pretest and posttest scores immediately and after using the STEAM-based food microbiology electronic booklet. Then, the N-Gain test was conducted to determine the increase in student scores. The results of the N-Gain test can be seen in Table 9.

Table 9. N-gain test results.

| Test | N-Gain Value | N-Gain Value (%) |
|---------------|--------------|------------------|
| Limited scale | 0.561 | 56.01% |
| Description | Medium | Effective enough |

Table 9 shows that the results of the N-Gain test obtained a value of 0.561, which is included in the moderate category. Thus, using STEAM-based food microbiology electronic booklets can improve students' critical thinking skills with a fairly good increase.

Discussion

Material experts' calculation results of the STEAM-based food microbiology electronic booklet validation assessment sheet show that the average percentage obtained from the two validators is 82% and 76% considered valid. Results obtained indicate that the material contained in the electronic booklet on food microbiology is in tune with food microbiology sub-CPMK and has been arranged systematically, using communicative language and equipped with pictures that support the explanation of the material so that it makes it easier for pupils to understand food microbiology material. This statement aligns with the opinion of Wafi et al. (2022), which states that the concepts presented must be coherent, from simple to complex. The use of language must be in line with students' cognitive level so they can easily understand the teaching material (Permatasari & Trisnawati, 2021).

Design experts gave an average percentage of 96% and 93% were very valid criteria. The data states that the presentation of the material has been specified very well and is in line with the STEAM components. In line with the research of Harlis et al. (2021), the booklet is also effective in increasing teaching objectives. Another study by Sofia et al.

(2020) showed a validity score of the STEAM-based module of 87.2%. Furthermore, a study by Hasanah (2022) obtained a validity score for the STEAM-based module of 89.85%, a very valid criterion. Layout validation got an average percentage of 95% and 90%. The data shows that the design and writing of the STEAM-based food microbiology electronic booklet have been made very well. In line with the statement of Masrifah et al. (2020), the booklet presentation contains short text and is equipped with images.

The effectiveness test of the electronic booklet was carried out with a pretest and posttest. The average pretest score obtained was 49.27, a low criterion. The average post-test score obtained was 76.13, which is a high criterion. Thus, a t-test was conducted to assess the difference in student scores immediately before and after using the STEAM-based food microbiology electronic booklet. The significance value of the t-test is $0.000 < 0.05$, so H_0 is rejected, and H_a is accepted. Thus, it is concluded that there is a significant difference in the pretest and posttest scores of pupils immediately and after using the STEAM-based electronic booklet. Then, the N-Gain test was conducted to measure the increase in pupils' critical thinking skills immediately and after using the booklet. The results of the N-Gain test obtained a value of 0.561, which indicates an increase in pupils' critical thinking skills in the moderate or quite good category. Therefore, the STEAM-based food microbiology electronic booklet effectively increases students' critical thinking skills.

This value was achieved by completing the material in the electronic booklet with images and videos. This is in line with Nikmah et al. (2017) opinion that to help pupils understand the teaching, it is necessary to include images and illustrations in the electronic booklet to arouse their curiosity. Apart from that, integrating STEAM in the electronic booklet also supports upgrading pupils' critical thinking skills. This aligns with the study by Rahayu et al. (2023), which states that upgrading pupils' critical thinking skills can be implemented with the STEAM application. In line with research by Zubaidah (2019), pupils' critical thinking skills can be increased with STEAM integration. This is because the integration of STEAM results in student-centered teaching activities that stimulate active student involvement (Pasca & Waluya, 2024).

CONCLUSION

Fundamental Finding: The results showed that the STEAM-based food microbiology electronic booklet is very valid for supporting teaching material and is quite effective for upgrading students' critical thinking skills. **Implication:** The development of STEAM-based electronic booklets used as teaching materials for lecturers to involve students actively and can be applied to other courses relevant to food microbiology. **Limitation:** The content in the STEAM-based food microbiology electronic booklet only consists of a few materials and limited references, and the effectiveness test was only conducted in one class, thus affecting the study results. **Future Research:** Further research needs to be done by applying the product on a large-scale test to measure students' critical thinking and 21st-century skills.

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