

# Development of Bacteriology Textbook based on Research on Mn Bioremediation in Bacteriology Course

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**Abstract:** This research aims to produce a textbook based on the results of the research on the ability of bacteria to degrade heavy metals. The research was conducted using the ADDIE model with a series of tests such as a validity test, practicality test, and textbook effectiveness test. The textbook is validated by 3 experts: learning experts with a score of 91% (valid), materials experts with a score of 100% (valid), and practitioners with a score of 95% (valid). Practicality test using student responses from individual test (score 89%), small group test (score 90%), and field test (score of 89%). The effectiveness test of textbooks using an experimental method with a one-group pretest-posttest-only design by comparing the pretest and posttest scores using the Wilcoxon test and the N-Gain test. The Wilcoxon test results showed a significance value obtained smaller than 0.05 ( $p$ -value  $(0.000) < 0.05$ ), this shows that there is a significant influence between the pretest and post-test scores. The N-Gain results were at a score of 0.4, which means that the improvement experienced by students was at a moderate level. Based on the validity, practicality, and effectiveness scores, it can be concluded that the textbooks are valid, practical, and effective.

**Keywords:** ADDIE model; Effectiveness; Practicality; Textbook; Validity.

## Introduction

Maintaining a quality education system at the university is carried out by drawing up a college curriculum based on the Indonesian National Qualifications Framework (KKNi). KKNi is a statement of the quality of human resources whose qualifications are based on levels of competence specified in the learning outcomes formula (Kemenristekdikti, 2015). Therefore, preparing curricula for higher education acquires its autonomy but remains in line with the National Standard of Higher Education (SN-Dikti).

SN-Dikti aims to guarantee the learning process on the curriculum of study, research, and dedication to the community organized by colleges throughout the territory of Indonesian law, achieving quality according to the criteria established in the National Standards of Higher Education (Kemenristekdikti, 2016). The learning outcomes that undergraduate-level students (Level 6) must have are being able to apply their field

of expertise and use science, technology, and art in their field to solve problems (Nasiruddin et al., 2023). Furthermore, students must also master the theoretical concepts of a field of science in depth, and be able to formulate solutions to procedural problems. Students must also be able to make the right decisions based on information and data analysis, be able to guide them in choosing various alternative solutions independently and in groups, and be able to take responsibility for their work and be given responsibility for achieving the organization's work results (Arthars et al., 2024; Teshome et al., 2024).

One attempt to realize the accessibility of such lectures is by strengthening students' understanding of the science they have as a basis for solving environmental problems around them (Abbas et al., 2022). The stronger the concepts of science students have, the better their ability to solve the problems they encounter (Munfaida et al., 2022). The interaction of students with issues in the field and finding problems

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contextual to student life is a fundamental process in improving their understanding of science (Prasetyo & Perwiraningtyas, 2017). Therefore, the presentation of field problems in lecturing activities is highly recommended to be given to students.

Studying bacteria and their uses is part of a course at Bengkulu Muhammadiyah University. The results of interviews with the bacteriology lecturer revealed that the lecturer had a lot of difficulty teaching the Bacteriology course due to the limitations of the textbooks. The students' needs analysis showed they wanted a textbook to help them understand the bacteriology lesson material. The lack of relevant resource books is a significant obstacle for students in understanding a variety of courses, including courses on bacteriology (Johnson, 2016). Teaching books are one of the tools that must be available to support educational activities in the university (Anggela & Darvina, 2013; Weng et al., 2018). The book plays a significant role in achieving learning access (Fatmawati et al., 2022; Wresni et al., 2023). That is, it is in the field of knowledge so that the college graduates have equality with the formula of the level of breadth and depth of the study materials listed in the Learning Content Standard in SN Dikti (Kemenristekdikti, 2020).

The development of a research-based bacteriology textbook has never been carried out before, so it is hoped that this book can be used as a source of information in textbooks for students who want to study bacteria. The textbooks developed are also adapted to the curriculum at universities (Ray, 2020). The book that will be created is the result of development during the research process and will be combined with materials obtained from other sources.

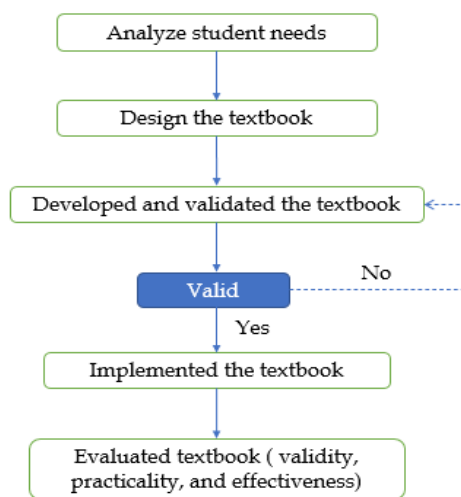
**Method**

Research and development of this textbook is carried out using the ADDIE instructional development model (Branch, 2009). The stages of the ADDIE model include Analysis, Design, Development, Implementation, and Evaluation. The overall research stages can be seen in the research shown in Figure 1.

The analysis phase is conducted to analyze the needs of students in the teaching activities. The student needs analysis found that students had difficulty studying abstract courses such as bacterial material because the microorganisms could not be seen directly. The solution to the student's needs analysis was the need for a research-based textbook so that students could contextually understand bacteria and the steps to isolate, identify, and test the bacteria.

The design stage is done by designing textbooks according to the curriculum in force at the college. The

textbook structure is modified from the Guidelines for Writing Granted Teaching Books of the Research, Technology, and Higher Education Department (Kemenristekdikti, 2016). The textbooks in the future design will be tested for validity by materialists, learning experts, and educational practitioners. After conducting the validity test, a practicality test is carried out for students using the student response lift after using the textbook.



**Figure 1.** Research flow

The development phase is carried out by carrying out the formative revision of the advice of the material expert validator, the validator of the learning expert, and the validation of the educational practitioner expert. Validation measurement indicators can be seen in the following Table 1.

After obtaining the validation results from each validator, a further classification of validation outcomes is carried out referring to (Akbar, 2017) with the criteria as shown in Table 2.

The Implementation and Evaluation phase is a phase in which students test their textbooks and evaluate the practicality of the textbooks that have been developed. The practicality of the textbook is measured from the student's responses obtained from the filling of student responses. Student responses being tested are individual student responses, small group student responses, and student responses to field tests. The criteria for assessing the practicality of textbooks can be seen in Table 3.

After conducting a validity test and practicality test of the textbook, the next stage to measure the suitability of the textbook being developed is to test the effectiveness of the textbook. Testing the effectiveness of textbooks was carried out using an experimental method with a one-group pretest-posttest-only design (Fraenkel et al., 2012), using one experimental class that

used bacteriology textbooks for one semester. The samples used in this experimental activity were biology students at Tribhuana Tunggaladewi University, Malang.

The design of experimental activities can be seen in Table 4.

**Table 1.** Validation measurement indicators

Validation	Indicator	Scores
Learning expert validation	1. Legality and morality	Score 5: Excellent
	2. Content validity	Score 4: Very good
	3. Presentation components	Score 3: Good
	4. Components of literature	Score 2: Fair
	5. Book accessories components	Score 1: Poor
Matter expert	1. Matter coverage	Score 5: Excellent
	2. Material accuracy	Score 4: Very good
	3. Material components	Score 3: Good
	4. Sub-matter accurateness	Score 2: Fair
	5. Material modernity	Score 1: Poor
	6. Presentation of textbooks	
Practitioner expert	1. Relevance	Score 5: Excellent
	2. Accuracy	Score 4: Very good
	3. Presentation of textbooks	Score 3: Good
	4. Language	Score 2: Fair
	5. Reading	Score 1: Poor

Source: (Akbar, 2017)

**Table 2.** Validity criteria instrument

Validity criteria (%)	Level of validity
85.01 - 100.00	Valid, can be used without revision
70.01 - 85.00	Quite valid, may be used but requires minor revision
50.01 - 70.00	Less valid, recommended not to be used because it requires significant revision
01.00 - 50.00	Invalid, or should not be used

Source: (Akbar, 2017)

**Table 3.** Criteria of practicality of teaching books

Practical criteria (%)	Practical level
81-100	Practical
61-80	Pretty practical
41-60	Less practical
21- 40	Not practical
0 - 20	Very unpractical

Source: (Akbar, 2017)

**Table 4.** Research design

Pretest	Treatment	Posttest
O1	X	O2

Source: (Fraenkel et al., 2012)

The level of textbook effectiveness is measured by comparing the pretest and posttest scores. A comparison of pretest and posttest scores was carried out to see whether the difference in scores between the two was significant or not. Before measuring the level of effectiveness of the textbook being developed, the pre-test and post-test scores that have been obtained are first tested. The prerequisite test carried out is to

measure the normality and homogeneity of pretest and posttest data. Normality and homogeneity data then become a reference for further measurements, namely by using parametric or non-parametric measurements.

After testing the effectiveness of the textbook, the next step is to determine the N-Gain criteria from the difference in pretest and posttest scores. The N-Gain test functions to measure the level of difference between students' pretest and posttest scores. The criteria for obtaining the N-Gain value can be seen in Table 5 below:

**Table 5.** N-gain criteria

Score level	Criteria
$g > 0.70$	High
$0.3 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

Source: (Hake, 1998)

## Result and Discussion

Bacteriology courses are so abstract that students need other learning sources that can motivate students and better understand the courses. One of the learning resources that can help students understand them is a textbook developed according to the needs of students (Wismanto & Ullumudin, 2022). The textbook is intended for students of biological education who take Bacteriology courses. Besides, it is also expected to be used in other Schools such as Microbiology, Biotechnology, and Genetics because of the similar material characteristics (Sampath, 2023).

The Bacteriology textbook developed is based on the results of research on bacteria in the laboratory. The use of research in the textbook can help students understand science materials (Chi et al., 2023). The images and illustrations presented in the textbook are images taken while conducting research activities so that students become increasingly interested in using textbooks. An interesting textbook will be very useful in increasing student interest and knowledge. Through the development of this research-based bacteriology textbook, students are expected to understand and follow every course and process of research activities written in the book (Mawarnis et al., 2023; Supratman,

2023). Through the understanding of the entire research process contained in the textbook, students become increasingly understanding and able to deal with the abstract things perceived before.

The research carried out to compile the textbook consists of three stages: isolation of indigenous bacteria, identification of the ability of native bacteria to degrade heavy metals, and discovery of genes that play a role in degrading heavy metals in bacteria. The results of bacterial research in the laboratory were used as material for the preparation of the textbook developed. The textbook developed has the following structure:

**Table 6.** Structure of the developed textbooks

Textbook structure	Content
Title or identity	Contents of the title of the textbook
Introduction words	Gives a brief explanation of the content of a textbook developed
Use instructions books	Giving instructions on the components contained in the textbooks
Content lists	Given a list of the contents of textbooks, tables, and picture lists
Materials	Materials per chapter adapted to the curriculum of the College
Summary	Giving a summary of the material in each chapter
Competence tests	Give information about multiple choices and descriptions to measure the competence of students
Library lists	Given the list of references used in the compilation of the textbook

After the textbook contents are made following the structure in Table 6, the validation of textbooks by three experts is carried out: validation by the learner,

validation by the material expert, and validation by the practitioner of education. The validation results by the three validators can be seen as follows:

**Table 7.** Results of expert validation

Assessment aspects	Percentage (%)	Description
Learning expert validation	91	valid
Matter expert	100	valid
Practitioner expert	95	valid

**Table 8.** Results of student response to the textbooks

Assessment aspects	Individual tests	Small group trials	Field trials	Average score	Description
Pleasant	87	87	92	89	practical
Useful	93	96	97	95	practical
Stimulating	87	87	87	87	practical
Disclosure	93	89	88	90	practical
Effective	87	87	85	86	practical
Clear	93	87	85	88	practical
Relevant	87	87	87	87	practical
Practical	87	87	83	86	practical
Helping	87	96	93	92	practical
Accurate	93	91	87	90	practical
Useable	93	93	93	93	practical
Modern	87	87	85	86	practical
Important	93	91	93	92	practical
Attractive	87	89	89	88	practical
Efficient	87	87	87	87	practical
Low Cost	87	87	92	89	practical
Appreciated	93	87	89	90	practical
Average	89	90	89	89	practical



Table 7 shows that the textbooks developed have met criteria with valid categories and can be used for field implementation. The next step is to test the practicality of a textbook developed through student responses to the use of the textbook that has been developed. The student's responses were individual student responses, students' responses to small groups, and students' responses to field trials (Iriani et al., 2019; Pujawan, 2019). The response range used was adopted from (Thiagarajan et al., 1974). The overall student response results can be seen as follows (Table 8):

The individual test in Table 8 was conducted on three students through a given response lift. The small group test was performed on nine students and the field test was carried out on 15 students. The test results on the whole group showed that the textbooks developed were practical and ready to be tested in the field.

In the field trials, the highest score is on useful aspects with a score ratio of 95%, this is because the book is very useful in helping students understand the material about bacteria because the textbook is designed research-based so that it can present the research procedure on bacteria in detail so that students can understand it well (Marandy, 2023). The textbook also comes with a variety of information from valid sources so it can be additional material for students. The other high score lies in the useful, helpful, and important aspects, it is because it is felt very useful for students to help understand material about the bacteria perceived abstractly during these days, especially with the presentation of a clear penalty flow accompanied by relevant material and in enriched with competence tests that can help students to deepen student understanding (Purwaningtyas, 2020).

This is an enjoyable, valuable, and valuable aspect because the textbook presents a clear and sequential documentation of the research process, ranging from the tools used to the bacterial results documented directly from the results of observations using a microscope. This live documentation makes it more interesting and enjoyable for students to study and can increase the curiosity of students and the material presented is useful to students to deepen the material they are studying. A textbook that has a visual presentation of the material plays a major role in improving student understanding. The textbooks are also considered valuable to students because the material is presented following the material that they want to learn.

After conducting a validity test and practicality test, the next stage is to test the effectiveness of the textbook. The effectiveness test results were obtained by comparing the pretest and posttest scores obtained

by students using the Wilcoxon test and the N-Gain test. The comparison of student pretest and posttest scores using the Wilcoxon test can be seen in the following table:

**Table 9.** Comparison of pretest and posttest scores on student learning outcomes using the Wilcoxon test

Score	Sig
Pretest-posttest	0.000

The results of the Wilcoxon test in Table 9 show that the significance value obtained is smaller than 0.05 (p-value (0.000) < 0.05). This shows that there is a significant difference between the pretest and posttest scores obtained by students. The significant difference in scores between the pretest and posttest scores shows that the use of textbooks in learning activities has a significant influence before and after implementation. The next step after carrying out the Wilcoxon test is to determine the N-Gain criteria from the difference in pretest and posttest scores. The N-Gain test aims to see the increase in student scores from the difference between the pretest and posttest scores carried out. The N-Gain test results can be seen in Table 10 as follows.

**Table 10.** N-Gain score

Postest	Pretest	N gain
69.0	50.4	0.4

The N-Gain score is 0.4, which means that the improvement experienced by students is moderate according to the N-Gain score assessment criteria. The increase in pretest and posttest scores with moderate criteria shows that the implementation of textbooks can improve student learning outcomes. This is in line with the score obtained from the Wilcoxon test results, which also showed that there was a significant increase in student pretest and posttest scores.

The level of effectiveness of the textbooks being developed is measured by comparing the pretest and posttest scores given to students (Hamidah et al., 2020; Rizki & Wildaniati, 2015). Pretest questions are given to students before implementing the textbook in class, while posttest questions are given to students after implementing the textbook (Wahab et al., 2021). The pretest and posttest scores obtained by students are first tested for normality and homogeneity of the data to determine further tests, namely parametric tests or non-parametric tests (Widana & Muliani, 2020). The normality test of pretest and posttest data was carried out using SPSS 26 using the Shapiro-Wilk test (Latief, 2016). The results of the Shapiro-Wilk test show that the p-value found is smaller than 0.05 (p-value > 0.05). This

shows that the pretest and posttest data were not distributed normally (Kadir, 2015; Priyatno, 2009).

After getting the results of the data normality test, the next step is to test the homogeneity of the pretest and posttest data. The homogeneity test is also a prerequisite test for carrying out statistical tests to determine further tests, such as parametric or non-parametric tests (Doyan et al., 2015; Widana & Muliani, 2020). The homogeneity test of pretest and post-test data was carried out by the Levene test (Kadir, 2015). The homogeneity test results show that the significance value obtained is greater than 0.05 ( $p\text{-value} > 0.05$ ). This shows that the pretest and posttest data are homogeneous. After knowing the normality and homogeneity of the pretest and posttest data, the next step is to carry out a comparative test between the pretest and posttest scores to see whether there is a significant difference between students' pretest and posttest scores (Ismawati & Prasetyo, 2020). A significant difference will indicate that learning using textbooks that have been developed can improve student learning outcomes before and after treatment. The test used to compare pretest and posttest scores was the non-parametric Wilcoxon test because one of the data was not normally distributed (Kadir, 2015).

The Wilcoxon test results show that the significance value is smaller than the  $\alpha$  value ( $p\text{-value} < 0.05$ ), which means that there is a significant difference between the pretest and posttest values. The significant difference between pretest and posttest scores shows that the implementation of textbooks is very effective in improving student learning outcomes (Islamiyati et al., 2021; Latief, 2016; Li & Wang, 2024; Nurhidayat et al., 2012). The increasing effectiveness of textbooks in the research process is caused by several factors such as the use of cooperative models during the implementation process (Cortázar et al., 2022), the use of LKM which can help students understand the flow of the material provided, and the existence of practicum activities during the implementation process (de Jong et al., 2023; Ng, 2023; Rokhiyah et al., 2023). Practical activities can actively involve students in learning activities (Septyowaty et al., 2023) and train students to collaborate in carrying out scientific procedures to deepen their understanding (Hestiningtyas et al., 2023).

The use of the cooperative model has been proven to be able to improve student learning outcomes (Fahrudin et al., 2016; Jung & Lee, 2022). Cooperative learning provides many benefits for students during learning activities, such as increasing self-confidence, making students more active during the learning process, sharing information through group discussions, increasing the sense of responsibility towards group friends, and increasing positive

interactions among students ("Perbedaan Pengaruh Model Pembelajaran Kooperatif Tipe Stad Dan Tipe Jigsaw Terhadap Hasil Belajar Fisika Ditinjau Dari Motivasi Belajar Siswa," n.d.). Cooperative learning is synonymous with forming study groups in lectures.

Apart from using cooperative learning, the use of LKM also influences improving student learning outcomes (Hidayati et al., 2023). The results of literature studies show that the use of LKM can help students to better understand the lecture material being given (Saregar, 2016; Sari & Bare, 2018), make students more active, and provide additional notes for students to understand the material given (Rezeki et al., 2022). The use of LKM also allows students to discuss and share information with friends in their group which can increase enthusiasm for learning in their respective groups (Perdana & Ramadhona, 2021; Saija & Beay, 2022).

## Conclusion

The results from the developed bacteriology textbooks were considered valid by practitioners, learning experts, and material experts based on validity tests. Additionally, the textbooks are judged as practical for students based on results from individual, small group, and field testing. Additionally, the textbook was successful in raising student results, according to effectiveness tests from the N-Gain and Wilcoxon tests. Therefore, a bacteriology textbook has been developed and is valid, practical, and effective for students to utilize in their studies

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## Author Contributions

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## Conflicts of Interest

The authors declare no conflict of interest.

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