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The Need Analysis for Developing Microbiology Practical Program in the Topic of Heavy Metals Bioremediation Microorganisms

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Abstract: The involvement of bacteria in lowering the concentrations of heavy metal contaminants in the environment is one of the most recent topics of discussion in the field of microbiology. This topic hasn't been brought up much in microbiology lectures thus far in the classroom. Therefore, it is important to analyze the requirement for the construction of a microbiology practical model with the focus on investigating heavy metal-bioremediating bacteria as environmental polluting agents. The curriculum papers in the biology education study program were analyzed using quantitative and descriptive research methodologies, with a focus on the microbiology course. Additionally, this study used both closed- and open-ended questions. We studied a total of 45 fourth-semester microbiology students from four different institutions, six microbiology lecturers from several Indonesian universities, and four biology teachers from Tanjung Pinang. It was discovered that environmental bioremediation needs to be covered in more detail in microbiology lectures and practicum for aspiring biology teachers based on an analysis of the curriculum, students' perspectives, and instructors' perceptions. Lectures on the subject of heavy metal bioremediation should cover it in detail and should provide useful knowledge. The teacher believes that lab exercises have the potential to be a successful teaching method for this subject.

Keywords: heavy-metal bioremediation microorganism, microbiology lab, need analysis, practical model

Introduction

The growth of industry has the potential to boost local prosperity. On the other side, given the buildup of trash, including toxic and dangerous materials, it has a negative influence on the environment (Patnaik, 2018). Previous studies have demonstrated that unsustainable industrial practices (such as tanning and the manufacture of synthetic materials) have a significant negative influence on human health and the environment, which results in complicated socio-ecological issues. Heavy metal is one of the environmental contaminants that results from numerous human activities. The amounts of heavy metals released into the environment, water, and soil has increased dramatically as a result of industrial activities (Hoque et al., 2018).

Heavy metal deposits prevent native biota from covering land effectively. When heavy metals combine with other environmental components including water, soil, and air, they can become extremely poisonous. The food chain can expose people and other living things (Ojuederie & Babalola, 2017). Exposure to heavy metals through living creatures' physiological systems can be a lethal poison (Mitra et al., 2022). The presence of heavy metals in aquatic ecosystems can harm physiological processes and potentially result in the death of aquatic biota, such as fish, which are crucial to the food chain.

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Without serious action, the polluted environment will lose its ability to function naturally, deteriorate in quality, and interfere with human health. The utilization of microbes like bacteria, molds, and fungi will be highly significant in reducing environmental pollutants and the toxicity of different pollutant chemicals. Microbes are currently used extensively in environmental control.

Alkaliphilic bacteria are one type of microorganism that has evolved to the environment that is heavily polluted with heavy metals. A biological process called "bioremediation" is mediated by microbes or other organisms (Pal et al., 2020). It is a sustainable method for environmental pollutant degradation and detoxification (Chakraborty et al., 2012). This particular bacterial species can endure in situations with high pH levels (above 8). Because of their capacity to reduce alkalinity biologically, tolerance to high ion and metal concentrations, and poor availability of carbon and organic resources, alkaliphilic bacteria are seen as potentially appealing alternatives for the treatment of industrial alkaline residues (Nogueira et al., 2017). Because heavy metals are naturally occurring substances that cannot be broken down and metabolized, the interaction of microorganisms (bacteria and fungus) with metals and the removal of metals from contaminated places is a special process. Instead, microbes have learned how to deal with these elements by binding metals intra- or extracellularly or converting them into less damaging chemicals to stop unwanted interactions in the host cell (Xu et al., 2020).

Environmental contamination should be a problem across all industries, but especially in education. An approach for preparing young people who are concerned about the environment is to educate aspiring biologists. Future educators can learn about the function of microorganisms that are crucial to minimizing environmental contamination from heavy metals through the study of microbiology. Even in the junior and senior high school levels, instruction on the function of microorganisms in health has been provided (Lecky et al., 2011). In order to gain knowledge about the variety of bacteria present in the environment that can negatively impact human health, molecular approaches have been used in university settings to characterize microbial communities (Park et al., 2021). However, the ability of bacteria to clean up the environment of toxins like heavy metals is not a topic covered in high school or college microbiology courses.

One of the required disciplines in university study programs in biology is microbiology. The topics covered in this course include microorganisms, their ways of life, their functions, and the laboratory procedures used to research them. The information covered in university microbiology courses contains tangible facts, concepts, principles, and lab methods. The macro-concepts of microbiology are the aspects of microbial life, including non-cellular groupings (viruses), eubacteria, archaebacteria, protists, fungus, and microscopic algae, as well as their function in life. Microbiological investigations also incorporate practical expertise in incubation methods, microbial isolation, and microbe identification.

Usually, didactic lectures and hands-on exercises go along with microbiology lectures. Practical activity is a crucial component of microbiology lectures since it helps students become more motivated, proficient, and scientifically minded (Khotimah et al., 2021). Students are typically taught microbiological laboratory skills using a lab activity guide that explains the actions to be taken, the processes to be followed, and the anticipated outcomes at the conclusion of the experiment in the lab reports (Matsuo et al., 2011). Students typically don't think critically or creatively, instead merely following simple rules. Furthermore, practical activities frequently downplay the significance of implications in real-world circumstances. In the meantime, because science is directly tied to reality, students who study it should be able to give their ideas to nature. Students must consider how to resolve issues that arise in the actual world.

It is crucial to discuss about the investigation of how microorganisms contribute to the restoration of heavy metal-polluted environments. The study of microorganisms in life, one of which is that they contribute to the degradation of environmentally harmful metals, However, no particular practicum activity in microbiology has been identified at multiple universities that instructs students to investigate this possibility in practicum activities (Prayitno, 2017).

Microbes and their activities have a wide-ranging and typically favorable impact on human function, the functioning of the entire biological community, and even the surface and atmosphere of the entire planet (Timmis et al., 2019). Incorporating microorganisms into the curriculum more often would not only increase our appreciation for the ecosystem we live in but will also help create citizens who are better able to make educated choices regarding environmental and health policy (Barberán et al., 2016). A lecture program (practical activities) that can help students undertake scientific studies on the potential of microorganisms as biodegradative agents for heavy metal waste in the environment is required in an effort to increase the contextuality of microbiology learning for prospective teachers.

Method

Overview of Design Study

Using both quantitative and descriptive approach, the research was carried out. In order to analyze the need

for the development of a microbiology practicum, this study focuses on three variables: students' perceptions of microbiology lectures, instructors' perceptions of the context of microbiology learning in both secondary school and university, and the content of the microbiology practicum syllabus in several universities in Indonesia. A closed questionnaire that was completed by forty-five (45) students enrolled in microbiology classes at four distinct state universities in Indonesia yielded the variable of student perception. Five secondary school science teachers in the Kepulauan Riau Province completed an open questionnaire to determine their students' perceptions of the microbiology material in biology courses. By looking at the curriculum documents for the Biology Education Study Program at four public and private universities in Indonesia, it was possible to determine the varying content of the microbiological practicum syllabus.

Data Collection

Students were asked to complete research questionnaires that contained 16 statements about how they saw microbiology lectures in terms of their delivery methods, access to learning resources and media, lecturer qualifications, and the range of the subject matter covered. In this context, microbiology lectures comprise both classroom theoretical instruction and laboratory application. Seven statements from the questionnaire, to which the teacher responded, covered various facets of the subject range of the biology lesson and biology learning techniques related to the discussion of microorganisms. A note sheet that condenses the essential information is the tool used to assess the microbiology curriculum's content at universities.

Internal Validity and Ethical Consideration

A validator with experience in the field of microbiology initially evaluates the research instrument created. The validator offers feedback on a number of test items that:

> "*Statements on the questionnaire must take note of and accurately reflect the significant issues that the research will address*."

Improvements were made to the item items in response to the validator's feedback, and as a result, the two validators concurred that all of the item items were practical to use.

All educators and students who participated in the study were given information about the study and data collecting from the researcher as part of the ethical considerations that went into it. Without any compulsion or implications for the evaluation of student learning outcomes, participation in this study is entirely voluntary.

Data Analysis

By calculating the percentage of respondents who chose "strongly agree," "agree," "disagree," or "strongly disagree," data on student replies to closed questionnaires were analyzed. By recapitulating the teacher's responses, categorizing them, and grouping them according to their similarity, the data analysis of the teacher's response to the open questionnaire was carried out qualitatively.

Result and Discussion

Curriculum Analysis

Four institutions' biology education study program's curriculum documents were subjected to a curriculum analysis (University A, B, C, and D). This study was done to get a general idea of what students learn in microbiology classes. Table 1 displays the investigation's findings.

Table 1. Summary of learning outcomes for microbiology courses

Aspects of learning outcomes	Competency description
Attitude Aspect	Students are able to demonstrate an attitude of gratitude for the world of microorganisms as God's creation which cannot be replaced
	Students are able to demonstrate social sensitivity and be able to work together in providing solutions to problems in society and the environment from the point of view of microbiology
	Students are able to to play a role in improving the quality of life in society, nation, state, and the progress of civilization by implementing the role of microbiology
Knowledge aspect	Students are able understand the history of the development of microbiology
	Students are able to master the theories, concepts, principles and procedures of microbiology through the use of relevant digital information technologies
	Students are able to analyze the importance and role of microorganisms in various fields of health, food, industry, and environmental remediation
	Students are able to evaluate the implications of technological developments on microorganisms for the benefit of human civilization

Aspects of learning outcomes	Competency description
	Students are able to master basic concepts in the field of microbiology research and their implications for the development of microbiology
Skill aspect	Students are able to think logically, critically, systematically, and innovatively in the development or implementation of microbiology
	Students are able to examine the implications of the development or implementation of microbiology to generate solutions, ideas, designs, or criticisms as well as compose a scientific description of the results of their studies.
	Students are able to make appropriate decisions in the context of solving problems in their field of expertise, based on the results of analysis of information and data
	Students are able to communicate ideas with scientific arguments responsibly and based on academic ethics, through various media to the academic community and the wider community

According to Table 1, there are three components that must be met in order to meet the learning objectives for microbiological courses. These components are attitudes, knowledge, and skills. The attitude component is connected to the spiritual attitude of gratitude for God's creation of the microbiome. The attitude component also involves social attitudes toward society and the environment as well as the capacity to contribute to raising people's standard of living through the use of the scientific discipline of microbiology. The knowledge component includes knowledge of the background of the development of microbiology, as well as fundamental theories, concepts, principles, and practices of microbiology as they are explored through relevant technology, as well as knowledge of the function of microbes in various aspects of life and the technological implications of microorganisms for the advancement of human civilization. Aspects of abilities include the ability to think critically, methodically, and creatively; the ability to come up with ideas, designs, criticisms, and solutions; the ability to make decisions regarding problems; and the ability to organize and communicate ideas.

One of the fundamentals of curriculum analysis, which focuses on examining this course's accomplishments, is that students must study microbiology from the perspective of the environment and community context in order to attain certain attitudes and knowledge requirements. Students must be able to show social awareness when it comes to environmental concerns that are pertinent to the function of microbes in various aspects of life. The use of microorganisms in environmental remediation is one of them.

Additionally, as shown in Table 2, the outcomes of the analysis of the practicum syllabus in four Biology Education study programs in Indonesia provided details regarding the content of the practicum contents.

Based on a review of the course content at four Indonesian universities, it was determined that the microbiology practicum covers seven primary topics: the creation of microbial growth medium, sterilizing techniques, aseptic techniques, isolation techniques, microbial cultivation, microbiological identification, and enumeration. The topics of quantitative and qualitative coliform tests, antimicrobial activities tests of medicinal plants, microbes from various environments, food microbes (fermentation), and microbiological tests of water quality are displayed as examples of practical activities that help contextualize microbiological topics.

Table 2. Summary of microbiology practical topics at universities in Indonesia

University A	University B	University C	University D
Introduction to microbiology lab tools	Manufacture of microbial medium	Safety Lab and Equipment Introduction	Introduction to Laboratory Tools and Equipment.
Media manufacture and sterilization	Isolation of microbes from food and beverages through quadrant streak technique	Microbial Growth Media manufacture	Microbial Characteristics Microorganisms Staining
Inoculation of bacteria and fungi	Observation of bacterial colony morphology	Sterilization, Aseptic Technique, Isolation and Purification Technique	Media manufacture Microbial isolation technique
Isolation of pure cultures and manufacture of microscope preparations	Microbiological quantitative analysis of food and beverages	Microscopy, Microbial Morphology and Staining	Antimicrobial Activity Test
Microbial cell staining	Bacterial Gram stain	Anti-microbial and Oligodynamic Efficacy	Microbial growth curve measurement
Antimicrobial sensitivity test by agar diffusion method (resistance test)	Testing the antimicrobial power of medicinal plants on microbial growth in vitro	Microbes from Various Environments Around Us	Microbial Quantity (Counting the Number of Cells of Microorganisms)

University A	University B	University C	University D
Qualitative and quantitative tests of coliform bacteria	using the paper disc method	Food Microbes: Optimal Environmental Conditions in Fermentation Microbiological Test of Water Quality (Coliform analysis)	

There are more practicum subjects at University C than at other universities. The themes for the contextual practicum are more varied in the campus practicum syllabus. Data from the four institutions' microbiology practicums suggest that context is an essential component of the practicum, but the structure of the microbiology practicum material does not yet include a context for the role of microorganisms in lowering heavy metal contamination in the environment.

Student perception

The information on how students perceive about microbiology lectures is crucial for revealing how microbiology learning and practicums are implemented from the viewpoint of learning strategies, the availability of supporting facilities for lectures and practicums, lecturer competencies, and the study's scope. Figure 1 illustrates data from the research that was done on how students felt about microbiology lectures.

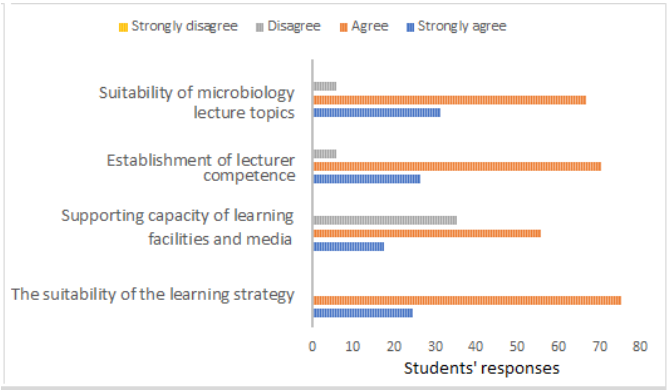

Figure 1. Students' views on microbiology lectures

The majority of students have a favorable opinion of lecture tactics, facilities, lecturer competences, and the range of microbiology studies, according to questionnaires completed by 45 students from four different Indonesian institutions. However, more than 50% of students reported that the practicum did not go well in terms of implementation. This is possibly because the pandemic conditions still force the execution of the microbiology practicum to be done in a sparse and independent manner. Students believe the practicum assistance facilities are sufficient, nonetheless. Students feel that lecturers can create practicums that are excellent, despite the fact that they have not been permitted to conduct practicums on campus.

Students also stated the microbiological practicums topic that had been conducted on their individual schools. The open-ended questions that students were asked to complete led to the following summaries of the practicum topics:

1. Sterilization of equipment in the microbiology laboratory
2. Cultivation of Nutrient Agar and Potato Dextrose Agar media
3. Bacterial inoculation and isolation
4. Observing the morphology of bacteria, fungi, microalgae, and protozoa using a microscope
5. Utilization of microorganisms in reducing environmental pollution
6. Bacterial cell staining (Gram stain and endospore stain)
7. Antimicrobial test of various substances
8. Winogradsky column
9. Coliform analysis

It is more focused to examine how students perceived about the lecture experience (including the practicum) in regard to understanding the role of microorganisms in environmental bioremediation, particularly from heavy metal contaminants, in future data gathering.

Table 3. Students' perception of microbiology practicum content

Questions	Yes (%)	No (%)	Not sure (%)
Do microorganisms play a role in reducing levels of heavy metal pollution in the environment?	79	11	10
Does the microbiology course provide knowledge about the role of microbes in reducing environmental pollution?	93	7	
Does the microbiology course provide knowledge about the role of microbes in reducing heavy metal pollution in the environment?	71	29	
In the area you live in, is there any form of heavy metal pollution that occurs?	32	40	28

Did the microbiology practicum that you took provide insight and skills about the role of microorganisms to reduce the impact of environmental pollution (heavy metal pollution)?	10	90
Is it important to study the role of microorganisms in reducing the impact of environmental pollution (heavy metal contamination)?	75	25

Perceptions of instructors (biology lecturers and teachers)

Additionally, the data recap was gathered from the open-ended questionnaire that the biology instructor completed and is displayed in Table 4. Through data exploration, high school biology teachers have learned several significant facts regarding the usefulness of teaching the subject of microbial degradation of heavy metal pollution through biology. According to the teacher, learning about microbiology in high school biology entails studying a variety of subjects, including the environment, biotechnology, and the diversity of living things. The importance of environmental pollution and how to deal with it, as well as the chance to develop students' higher-order thinking skills if critical topics were raised in the discussion, led all teachers to agree that the study of the role of microbes in heavy metal pollution degradation should be taught in biology classes. All teachers agree that there is consistency between this study and the competency criteria that must be met at the high school level in terms of both competency attainment and the sophistication of students' thinking.

All teachers responded that they had taught the subject of the function of microbes in the bioremediation of heavy metal pollutants, but only in brief conversations, and they provided examples of the many kinds of microorganisms involved in the breakdown of heavy metals. The teacher claimed that although many learning tactics, such as scientific preaching, discovery learning, lectures, and discussions, had been used to study the types and roles of microbes, no one had yet used the practical method to investigate this subject. There aren't many teachers who conduct practicum, particularly on the subject of the role of microbes in the degradation of heavy metals, but the teacher thinks that this practicum could be conducted in schools with facilities, infrastructure, and practicum modules that are on par with high school competency levels.

Table 4. Teacher's views on the contents of microbiology in biology classes and teaching opportunities in the context of heavy metal-degrading bacteria

Questions	Teachers' responses
In your opinion, what are the topics in biology subjects that are microbiological studies?	The topics are about bacteria, environment, biotechnology, cells, protists, fungi.
In your opinion, is it necessary to study the role of microbes in degrading heavy metal pollution taught in biology subjects?	Because of how concerning environmental contamination is right now, a distinct scientific study is required in order to discuss it. Yes. Biotechnology literature has already addressed the part that bacteria play in the breakdown of heavy metals. However, I believe it is important to teach in more detail and provide examples as the planet becomes more polluted and as the world becomes older so that kids understand and may play a proactive role in protecting the environment. It is essential since one of the subjects that students can practice in actual life is this one. Simply require students to comprehend
In your opinion, is a study on the role of microbes in reducing heavy metal pollution appropriate for achieving biology learning competence at the high school level?	It is pertinent because class X contains content on pollutants. In general, this is not an issue provided the studies and themes presented are appropriate for their level of thinking. It is suitable since it can promote the growth of higher-order thinking skills The fundamental skills of learning biology in high school include this subject.
Have you ever linked the discussion of biology with the role of microorganisms in degrading heavy metal pollution? Please provide an explanation!	Yes, I have, but only briefly, I have not yet discussed how the process of the role of microorganisms in degrading heavy metal pollution is. I only provide information, that heavy metal pollution can now be overcome with the help of microorganisms. Yes, I have tough biotechnology topic, but only limited to examples of microorganisms. Yes, I have, by giving an example of the role of bacteria

Questions	Teachers' responses
What are the learning strategies that you do in teaching biology topics related to microorganisms? Please write down some of the approaches/methods/learning models that have been implemented!	Discovery learning model that presents examples of diseases caused by microorganisms and various bacteria Scientific approach and discovery learning Discovery Learning and Problem Based Learning Lectures and discussion of discovery learning models
Please explain your opinion, can practicum activities regarding the role of microorganisms in degrading heavy metals be carried out at the high school level?	It can be done if the school facilities and infrastructure are adequate I never done a practicum related to the role of microorganisms in degrading heavy metals. It's possible, but it must be accompanied by a clear practicum module according to the high school competency level. It can be done if the environmental conditions support it There isn't any yet
According to you, if the context of the role of microbes in degrading heavy metal pollution can be taught at the high school level, then how is the appropriate learning strategy applied?	Through direct practice the degradation process of heavy metal pollution by microbes Scientific approach and project-based learning By watching videos, discussions, presentations

Discussion

Overall, curriculum analysis, content analysis, and investigate of student and instructor views all point out the importance of microbiological instruction for students of aspiring biology teachers. Students who complete this course will have understanding of the world of microbes and their function in life. Students that take microbiology classes gain the ability to think critically, solve problems, make decisions, and communicate their ideas. The course also offers the specific lab skills required to delve into the realm of microbes. Microbiology classes should emphasize religious attitudes, social sensitivity, and a desire to contribute to the improvement of social life, in addition to knowledge and abilities.

To achieve this goal, one of the important principles that must be considered in developing lecture programs or microbiology practicums is the contextuality of study material so that it can lead students to understand the real phenomena of everyday life. The contextuality of learning microbiology can also improve students' science process skills (Hasruddin et al., 2018). One of the essences of curriculum analysis that focuses on studying the achievements of this course is that in the achievement of attitudes and knowledge aspects, there are aspects of the contextuality of environmental and community conditions that need to be studied by students from a microbiological point of view. Students are expected to be able to display social sensitivity to environmental issues that are relevant to the role of microorganisms in various fields of life. One of them is the role of microorganisms in environmental remediation.

To develop study materials in microbiology practicums that can provide contextual insights to students is very broad in scope, because microbiology covers various fields of life. Currently, microbes have been widely used in environmental management, namely as organic waste decomposers (Elpawati & Sugiarti, 2019), oil decomposers in the sea (Titah et al., 2021), domestic waste decomposers (Fan et al., 2018), plastic decomposers (Anggiani, 2020), and heavy metal decomposers (Santini et al., 2015).

Heavy metal bioremediation is a real issue in various regions in Indonesia. The issue of heavy metal contamination is a challenge for the environment today because it can reduce the carrying capacity of the environment (Newsome & Falagán, 2021; Gaur et al., 2021). However, the results of the practicum content analysis conducted in this study indicate that the topic of bioremediation has not yet been studied in microbiology practicums in Indonesia. The environmental context that has been studied in the microbiology practicum course is water pollution and food contamination by microorganisms. The positive role of microorganisms in the field of life, especially in bioremediation, has not been studied in microbiology practicum. The same information was obtained from an open questionnaire filled out by students, confirming that there is no bioremediation context in microbiology practicum.

On the other hand, the perceptions of students, lecturers, and biology teachers provide the view that the study of bioremediation is important to study and is relevant to microbiology. However, the learning experience of students in microbiology lectures has not yet acquired practical skills regarding bioremediation. Students have a limited understanding of bioremediation. One of the reasons for this condition is the lack of easy-to-understand learning and literature on bioremediation (Astuti et al., 2021). Likewise, the teaching experience of lecturers and teachers is still minimal in teaching the context of bioremediation. Studying bioremediation needs to be done by students

in groups to be involved in experiments so they can see the bioremediation process itself (Kennedy & Sundberg, 2020).

Conclusion

According to the study's data analysis, there is potential to build microbiology practicum material that addresses relevant topics such how bacteria help reduce heavy metal contamination. The ability of the teacher or lecturer to contextualize science learning plays a role in this. Additionally, learning facilities must offer assistance, particularly for performing practical tasks in context. Learning about the background of heavy metal contamination and how microorganisms can lessen its effects is important for teacher professional development and education of aspiring educators. Therefore, it is reasonable to draw the conclusion that the context of microbiology practicum has to be developed, especially in the area of the role of microorganisms in reducing heavy metal waste in the environment, based on the study's overall findings.

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Author Contributions
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Conflicts of Interest
The authors declare no conflict of interest.

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