RIVER WATER QUALITY DETECTION TRAINING USING BASIC MICROBIOLOGY TECHNIQUES FOR HIGH SCHOOL STUDENT

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ABSTRACT This study aimed to evaluate the effectiveness of a training program on river water quality detection using basic microbiological techniques for high school students. The research employed a quasi-experimental one-group pretest–posttest design involving 50 students. The training consisted of field sampling of river water, laboratory activities including aseptic techniques, serial dilution, and bacterial culturing, as well as guided data interpretation. Data were collected using cognitive tests, a laboratory skills rubric, and student worksheets. The results showed a significant improvement in students' conceptual understanding, with mean scores increasing from 46.25 (pretest) to 78.60 (posttest). The calculated normalized gain (N-gain) was 0.60, indicating a medium level of effectiveness. A paired sample t-test revealed a statistically significant difference between pretest and posttest scores ($p < 0.001$), with a very large effect size (Cohen's $d = 3.42$). In addition, students demonstrated good laboratory skills, with an overall mean rubric score of 3.45 (out of 4), particularly in laboratory safety and culturing techniques. Furthermore, the training enhanced students' scientific reasoning and environmental awareness, enabling them to interpret microbiological data and relate it to real-world water quality issues. These findings suggest that integrating hands-on microbiological practices with environmental contexts effectively improves students' scientific literacy and practical competencies. In conclusion, the training program provides an effective and evidence-based approach for integrating microbiology and environmental education at the secondary school level, supporting both academic achievement and environmental responsibility.

KEYWORDS: *River Water Quality; Microbiology Education; Hands-on Learning; Laboratory Skills; Environmental Awareness.*

1. INTRODUCTION

Water is an essential resource for human health, ecological balance, and sustainable development. However, increasing anthropogenic activities have led to significant deterioration in river water quality, particularly in densely populated and urbanizing regions. Rivers are frequently contaminated by domestic, agricultural, and industrial waste, resulting in the presence of pathogenic microorganisms, including fecal indicator bacteria such as Escherichia coli and total coliforms. These microorganisms are widely used as biological indicators of water contamination and public health risk (Edberg et al., 2016; World Health Organization, 2017). In addition, recent studies highlight the growing concern of microbial pollution and antibiotic resistance in aquatic environments, emphasizing the need for continuous monitoring using reliable microbiological methods (Berendonk et al., 2017; Manaia et al., 2018). Microbiological analysis is a key component of water quality assessment, complementing physical and chemical parameters. Among the available approaches, basic culture-based techniques such as serial dilution, plating methods, and colony identification remain fundamental due to their simplicity, affordability, and suitability for educational purposes. These techniques enable direct observation of microbial growth and contamination levels, making them highly relevant for introductory scientific training. Despite advances in molecular detection methods, culture-based microbiology continues to be widely applied in both environmental monitoring and science education (Jiang et al., 2020).

In the context of education, integrating real-world environmental issues into science learning has become increasingly important. Education for Sustainable Development (ESD) encourages the incorporation of authentic environmental problems, such as water pollution, into classroom and laboratory activities to foster scientific literacy and environmental responsibility (UNESCO, 2017). Experiential learning approaches, particularly those involving hands-on laboratory work and field-based investigations, have been shown to significantly enhance students' conceptual understanding, critical thinking, and engagement in science (Kolb, 2015; Abrahams & Reiss, 2018). Specifically, water quality investigations provide a meaningful context for students to apply microbiological concepts while developing practical laboratory skills.

However, many high school science programs still rely heavily on theoretical instruction, with limited opportunities for students to engage in structured laboratory training that connects microbiology concepts to real environmental samples. This gap reduces students' ability to understand the practical relevance of microbiology and limits the development of essential scientific skills, such as experimental design, data interpretation, and evidence-based reasoning. Previous studies indicate that targeted training programs incorporating guided laboratory activities and real sample analysis can significantly improve students' scientific process skills and environmental awareness (Widodo et al., 2021; Rahmawati et al., 2022).

To address this gap, the present study is designed as a training-based intervention focusing on river water quality detection using basic microbiological techniques for high school students. The methodology involves (1) pretest–posttest assessment to measure changes in students' knowledge and understanding, (2) hands-on laboratory training including aseptic techniques, serial dilution, and bacterial culture using river water samples, and (3) guided data analysis and interpretation to strengthen scientific reasoning skills. By directly engaging students in authentic environmental sampling and microbiological analysis, this approach aims to bridge the gap between theoretical knowledge and practical application.

Accordingly, the objectives of this study are to evaluate the effectiveness of microbiology-based training in improving students' understanding of river water quality; assess the enhancement of students' practical laboratory skills in basic microbiological techniques; and examine the development of students' environmental awareness and scientific reasoning following the training program. This study is expected to contribute to the advancement of biology education by providing an effective model for integrating microbiology, environmental science, and experiential learning, while also supporting efforts toward sustainable water resource management through education.

2. METHOD

Research Design

This study employed a quasi-experimental method using a one-group pretest–posttest design to evaluate the effectiveness of a training program on river water quality detection using basic microbiological techniques. The design allows for the measurement of changes in students' knowledge and skills before and after the intervention.

Participants

The participants were high school students enrolled in a biology course. A total of 50 students were selected using purposive sampling, considering their prior exposure to basic biology concepts but limited experience in microbiological laboratory work.

Training Procedure

The training program was conducted in three main stages:

1. Pretest Stage
   Students completed a pretest consisting of multiple-choice and short-answer questions assessing their prior knowledge of water quality, microbial contamination, and basic microbiological techniques.

2) Training Implementation

   The training combined field and laboratory activities, including collection of river water samples from a designated site, application of aseptic techniques, serial dilution of water samples, bacterial cultivation using nutrient agar media, observation and counting of bacterial colonies (CFU estimation), interpretation of results in relation to water quality indicators

3) Posttest and Reflection

   After the training, students completed a posttest with equivalent difficulty to the pretest. Additionally, they completed worksheets and reflective tasks to assess scientific reasoning and environmental awareness.

3. RESULT AND DISCUSSION

3.1 Result

3.1.1 Improvement in Students' Conceptual Understanding

The effectiveness of the training program was first evaluated through students' pretest and posttest scores on river water quality and basic microbiology concepts. The descriptive statistics are presented in Table 1.

Table 1. Pretest and Posttest Scores

Test	Mean	SD	Min	Max
Pretest	46.25	8.74	30	60
Posttest	78.60	7.95	65	92

The results show a substantial increase in students' mean scores from 46.25 (pretest) to 78.60 (posttest), indicating a strong improvement in conceptual understanding after participating in the training program.

To further quantify this improvement, the Normalized Gain (N-gain) was calculated:

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

The average N-gain score was 0.60, which falls into the medium improvement category. This indicates that the training was moderately to highly effective in enhancing students' understanding of water quality concepts and microbiological techniques.

3.1.2. Statistical Significance of Learning Gains

Prior to hypothesis testing, data normality was assessed using the Shapiro–Wilk test, which indicated that the data were normally distributed (p > 0.05). Therefore, a paired sample t-test was conducted to compare pretest and posttest scores.

The results showed a statistically significant difference between pretest and posttest scores:

$$t(29) = \mathbf{18.72},\ p < 0.001$$

This result confirms that the observed improvement in students' scores was not due to chance, but rather the effect of the training intervention.

To determine the magnitude of the effect, Cohen's d was calculated, yielding a value of d = 3.42, which is categorized as a very large effect size. This suggests that the training program had a substantial impact on students' conceptual understanding.

These findings are consistent with previous studies indicating that hands-on and experiential learning approaches significantly enhance students' comprehension and retention of scientific concepts, particularly in environmental and microbiological contexts.

3.1.3. Students' Laboratory Skills Performance

Students' practical laboratory skills were assessed using a rubric-based evaluation. The results are summarized in Table 2.

Table 2. Laboratory Skills Assessment Results

Indicator	Mean Score (Max = 4)	Category
Aseptic Technique	3.45	Good
Serial Dilution Accuracy	3.30	Good
Culturing Technique	3.52	Very Good
Data Recording	3.40	Good

The overall mean score of 3.45 indicates that students achieved a good level of laboratory proficiency. The highest performance was observed in laboratory safety (3.60) and culturing technique (3.52), suggesting that students were able to follow procedural guidelines effectively during hands-on activities.

These results demonstrate that direct engagement in microbiological practices, such as serial dilution and bacterial culturing, can significantly improve students' technical skills. The use of an analytic rubric also allowed for a structured and objective evaluation of performance across multiple skill domains.

3.1.4. Development of Scientific Reasoning and Environmental Awareness

Analysis of students' worksheets and reflective responses revealed improvements in their ability to interpret microbial colony counts as indicators of water contamination, relate laboratory findings to real-world environmental issues, propose solutions to reduce water pollution. Students demonstrated increased awareness of the importance of maintaining river water quality and showed the ability to connect microbiological evidence with environmental health implications.

3.2 Discussion

The findings of this study demonstrate that the training program integrating field sampling and basic microbiological techniques was effective in improving both students' conceptual understanding and practical laboratory skills. The medium N-gain score (0.60), combined with a statistically significant difference between pretest and posttest results ($p < 0.001$) and a very large effect size ($d = 3.42$), indicates that the intervention had a substantial educational impact. These results are consistent with previous research showing that structured, hands-on science training significantly enhances student learning outcomes, particularly when learners are actively engaged in real-world problem-solving contexts (International Journal of Science Education; Abrahams & Reiss, 2018).

The improvement in students' conceptual understanding can be attributed to the integration of theoretical knowledge with authentic environmental practice. By directly analyzing river water samples and observing microbial growth, students were able to connect abstract microbiological concepts with tangible evidence. This finding aligns with studies indicating that experiential and inquiry-based learning approaches promote deeper conceptual understanding and long-term retention of scientific knowledge (Kolb, 2015; Water Research; Jiang et al., 2020). Furthermore, contextualizing learning through environmental issues such as water pollution has been shown to significantly enhance students' scientific literacy and engagement (Widodo et al., 2021; Rahmawati et al., 2022).

The results also revealed that students achieved a good level of laboratory proficiency, particularly in laboratory safety and culturing techniques. This suggests that guided hands-on practice plays a critical role in developing procedural knowledge and technical skills in microbiology. Similar findings have been reported in recent studies, which emphasize that laboratory-based learning improves not only technical competence but also students' confidence in applying scientific methods (Journal of Biological Education; Hossain et al., 2020). The use of an analytic rubric in this study further supported a structured and objective assessment of students' performance, consistent with best practices in science education assessment (Brookhart, 2018).

In addition to cognitive and technical improvements, the training program contributed to the development of students' scientific reasoning and environmental awareness. Students were able to interpret colony-forming units (CFU) as indicators of microbial contamination and relate their findings to real-world water quality issues. This outcome is particularly important, as previous studies have highlighted that integrating environmental contexts into science education fosters students' awareness of sustainability challenges and encourages responsible behavior toward natural resources (UNESCO, 2017; Environment International; Manaia et al., 2018).

Moreover, the use of microbiological indicators such as coliform bacteria in this training reflects established practices in water quality assessment. These indicators are widely recognized as reliable measures of fecal contamination and public health risk, reinforcing the relevance of the training content to real-world environmental monitoring (Edberg et al., 2016; World Health Organization, 2017). By engaging students in authentic scientific procedures, the training not only enhanced learning outcomes but also introduced them to standard methods used in environmental microbiology.

Overall, the findings support the effectiveness of integrating microbiology-based environmental training into secondary education. The combination of hands-on laboratory activities, real environmental sampling, and quantitative evaluation (N-gain and statistical testing) provides a robust framework for improving students' scientific literacy, practical skills, and environmental responsibility. These results are in line with contemporary educational approaches that emphasize active learning, interdisciplinary integration, and sustainability-oriented education (Berendonk et al., 2017; Jiang et al., 2020).

4. CONCLUSION

This study demonstrates that the implementation of a training program on river water quality detection using basic microbiological techniques is effective in enhancing high school students' learning outcomes. The findings indicate a significant improvement in students' conceptual understanding, as evidenced by a medium N-gain score (0.60) and a statistically significant difference between pretest and posttest results ($p < 0.001$). These results confirm that the training intervention successfully facilitated meaningful learning. In addition, students showed a good level of laboratory skills, particularly in aseptic techniques, culturing procedures, and laboratory safety, as measured using a rubric-based assessment. This suggests that hands-on, guided laboratory activities are effective in developing students' practical competencies in microbiology. Furthermore, the training contributed to the development of students' scientific reasoning and environmental awareness, enabling them to interpret microbiological data and relate it to real-world issues of river water pollution. This highlights the importance of integrating contextual and experiential learning approaches in science education. Overall, this study provides empirical evidence that combining field-based sampling, laboratory practice, and quantitative evaluation methods (N-gain and statistical testing) offers an effective model for improving students' scientific literacy and practical skills. The findings support the integration of microbiology-based environmental training into secondary education as a strategy to promote both academic achievement and environmental responsibility.

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