Journal of Multiscale Materials Informatics

Vol. 1, No. 2, August 2024
https://publikasi.dinus.ac.id/index.php/jimat/ ISSN 3047-5724
DOI: 10.62411/jimat.v1i2.11108

Enhancing School Waste Management with EcoViber Using the Waterfall Approach

Muh Dliyaul Haq[1*], Nayudin Hanif[2], Ayla Yuli Rokhman[3], Kiki Sukinawan[4]

[1]Faculty of Education and Psychology, Yogyakarta State University, Yogyakarta, Indonesia
[2]Chemistry Education Study Program, Yogyakarta State University, Yogyakarta, Indonesia
[3]Educational Technology Study Program, Surabaya State University, Surabaya, Indonesia
[4]Faculty of Education, Surabaya State University, Surabaya, Indonesia

Article Info
Received : 2 July 2024
Revised : 7 July 2024
Accepted : 8 July 2024

Keywords:
EcoViber application
Plastic waste management
Sustainability
Waterfall method

ABSTRACT

The research focuses on the development and implementation of the EcoViber application to address plastic waste management in school environments, specifically at SDN Perdopo 02. The study aims to tackle the issue of plastic waste accumulation through technological solutions, enhancing environmental awareness and operational efficiency. The application employs the waterfall method for development and features data collection, visualization, and educational tools to promote transparency and accountability. Comprehensive observations and interviews with seven teachers revealed significant improvements in waste management, with approximately 54.95 kg of plastic waste collected from January to April 2024. The findings highlight the practical implications of EcoViber in fostering a culture of environmental stewardship among school stakeholders. Despite its success, the study acknowledges potential biases in data reporting and the limited generalizability of results due to the focus on a single school. Future research should explore diverse settings and refine methodologies to enhance the scalability and long-term impact of EcoViber. Overall, the study demonstrates EcoViber's value as an innovative and effective solution for sustainable plastic waste management in educational settings.

Corresponding Author:
email: muhdliyaul.2022@student.uny.ac.id

1. INTRODUCTION

Plastic waste remains a significant environmental issue globally [1], [2], including within school environments. Despite efforts to address this problem, considerable challenges persist. Maintaining cleanliness in school environments is crucial for the health [3] and comfort of students and other school members. However, plastic waste continues to be a common sight in many schools, whether in school yards, classrooms, or other areas. Beyond its unsightly visual impact, plastic waste also poses deeper environmental and human health impacts [4], [5], [6].

Poorly managed plastic waste in school environments holds substantial potential for creating serious problems [7], [8], like affect human health, and destroy ecosystems [9], even posing threats to surrounding environments [10]. Health issues related to plastic waste include various cancers, diabetes, organ malfunctions, impacts on the skin and eyes, sensory organ damage, birth defects, and other adverse effects [11]. Scattered plastic waste can serve as breeding grounds for disease-causing organisms, facilitated by rainwater accumulation in plastic wrappers or within waste piles. Additionally, plastic waste can contaminate soil and water, disrupt natural ecosystems, and endanger wildlife living near school

environments [12]. These negative impacts extend beyond the school grounds, affecting the broader community surrounding the schools.

Handling plastic waste in schools is undoubtedly challenging. Despite existing regulations and policies on waste management, many schools face difficulties in effectively managing plastic waste [13], [14]. Factors such as lack of awareness about the importance of plastic waste management [15], resource constraints, and inadequate infrastructure [16] are significant barriers hindering efforts to manage plastic waste in school environments.

Therefore, innovation and concrete actions are needed to address this issue. One approach is to develop applications that can assist in managing plastic waste in schools. Previous studies highlight the success of innovative solutions, such as smart bins and collaborative applications, in optimizing household plastic waste management in Quezon City, Philippines [17]. Similarly, the Reciclos application, a web-based platform utilizing QR codes on recycling bags, has successfully promoted sustainable waste management practices and enhanced environmental consciousness [18]. In the context of school environments, such applications should provide practical, efficient, and accessible solutions for all parties involved in plastic waste management at schools. Thus, these applications are expected to increase awareness and participation among all school members in efforts to manage plastic waste, thereby contributing to creating clean, healthy, and sustainable school environments.

One proposed innovation is the development of the EcoViber application. EcoViber is a digital platform designed specifically to aid in plastic waste management within school environments. Through EcoViber, users including students, teachers, and other school members can easily record, sort, and catalog plastic waste collected within the school environment. Additionally, EcoViber includes features aimed at enhancing engagement and participation of all school members in efforts to manage plastic waste, such as tips on environmentally friendly plastic waste management.

With EcoViber, it is expected that plastic waste management in schools can become more effective and efficient. Moreover, EcoViber is anticipated to serve as a means to increase awareness and participation among all school members in environmental preservation efforts. Thus, EcoViber is expected to make a positive contribution to creating clean, healthy, and sustainable school environments, supporting schools in fulfilling their vision and mission to educate environmentally conscious young generations.

2. METHODS

The research employs the waterfall method for its straightforward approach to software development [19]. This methodology is chosen for its structured sequence, where each phase is completed before moving to the next [20], [21], [22], as illustrated in Figure 1. This sequential process ensures a systematic and uninterrupted progression [23], which is beneficial for projects with well-defined and stable requirements. The waterfall method was preferred over other methodologies due to its clear delineation of project phases, providing clarity in development milestones and suitability for effectively managing defined project scopes. In this initial stage of development, data is systematically gathered through observations and interviews with various stakeholders at SDN Perdopo 02. The goal is to comprehensively understand project requirements and establish clear objectives for the system.

With the requirements established, the design phase commences. Here, the team finalizes the system architecture and user interface to ensure alignment with project specifications and user needs. Once the design is approved, the development team proceeds to build the system according to the outlined specifications. This phase involves coding, component integration, and system configuration using the Google AppSheet platform for its efficiency and adaptability.

The subsequent testing phase spans from January to April 2024, rigorously evaluating the system with feedback from 10 students in grades 4 to 6 at SDN Perdopo 02 using a 5-point Likert scale across 10 structured questions. This evaluation assesses various aspects such as (1) ease of use, (2) interface design, (3) effectiveness of visual guides for plastic waste processing, (4) usability of the waste recording feature, (5) comprehensibility of reports and graphs, (6) usefulness of environmental tips, (7) motivation from the ranking system, (8) technical reliability, (9) impact on environmental consciousness, and (10) overall

satisfaction with the EcoViber application. This process aims to refine the system based on user feedback, enhancing its effectiveness in promoting sustainable waste management practices within the school community. After successful testing, the system is put into operational use. Continuous maintenance activities are essential to uphold its performance, resolve any newly arising issues, and integrate required updates or improvements to enhance functionality progressively. Maintenance also encompasses rectifying errors that may not have been detected during earlier stages [24].

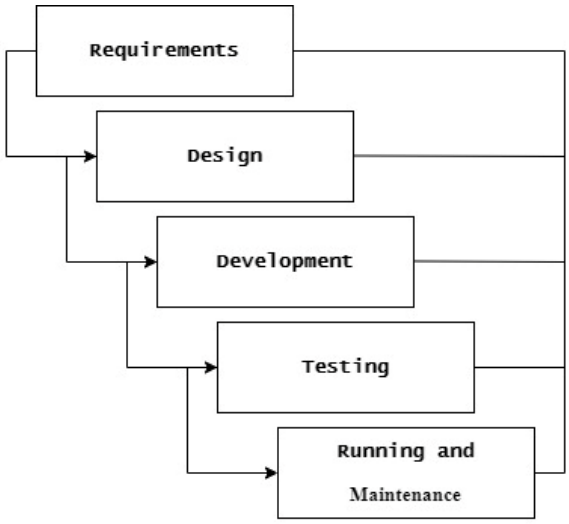


Figure 1. Waterfall Methodology

3. RESULT AND DISCUSSION

3.1. Requirements and Design

Based on the results of in-depth observations and interviews with seven teachers at SDN Perdopo 02, the requirements for the EcoViber application are comprehensively outlined in Table 1. This table encompasses various critical aspects aimed at supporting effective and efficient plastic waste management within the school environment.

Table 1. Criteria and Indicators of the EcoViber Application

Criteria	Indicator	Description
User-Friendly Interface (UI)	Intuitive Navigation	Menu and navigation that is easily understandable by all users.
	Responsive Design	Adaptive interface across various devices such as tablets, smartphones, laptops, or desktops.
	Simple Language Usage	Easily understandable language and avoidance of technical terminology.
Plastic Waste Management	Waste Recording	Feature to record the amount of plastic waste collected in grams and kilograms.
	Data Analysis	Reports and graphs for analyzing the collected waste data.
	Sorting Guidelines	Visual guides and tutorials on how to properly sort plastic waste.
	Ranking/Reward System	Rewards for users actively participating in plastic waste management.

The tools utilized for developing the EcoViber application include Google AppSheet and a weighing scale. Google AppSheet provides a low-code development environment (LCDP) that supports the creation of software applications using various data sources such as Google Sheets, Dropbox, and Office 365. It enables users with diverse backgrounds to design and develop applications customized to their specific needs [25]. Additionally, the weighing scale is equipped with measurements for grams (g), ounces (oz), pennyweights (dwt), carats (ct), and grams. It plays a crucial role in accurately weighing the amount of plastic collected in plastic bottles, ensuring precise data management throughout the waste collection process.

Next steps involve designing the application using a flowchart as depicted in Figure 2. This application serves two user roles: administrators and general users. Administrators are responsible for weighing the plastic waste deposited into used plastic bottles and entering the weight data into the application after logging in. This data will be visualized on a dashboard featuring reports on the amount of plastic waste collected per class and graphs displaying waste collection trends. On the other hand, general users can monitor the progress of plastic waste collection without logging in, observing accumulated waste amounts and developments over time. Thus, the application is designed to facilitate plastic waste management in school environments more efficiently and effectively, enabling easy and accurate monitoring by all involved parties.

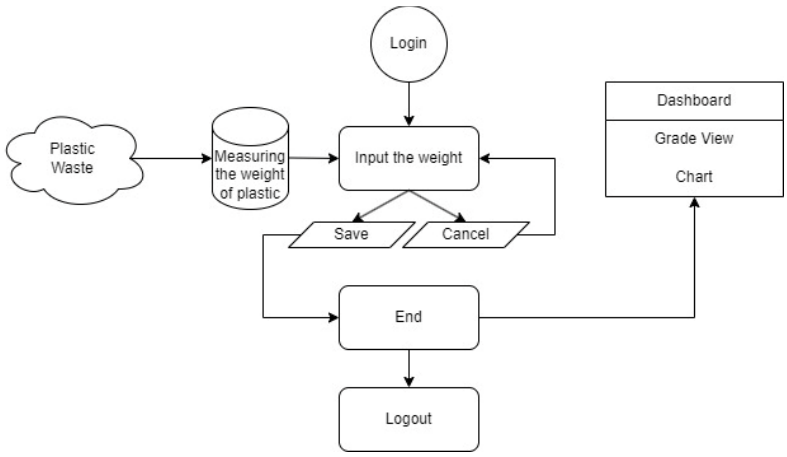


Figure 2. EcoViber Application Flowchart

3.2. Development and Testing

The EcoViber application is developed using Google AppSheet, integrated with a Google Sheets database. This integration ensures seamless access on desktop and mobile devices, providing flexibility and convenience for users. Figure 3 illustrates the detailed database structure and framework compatibility across desktop and mobile platforms.

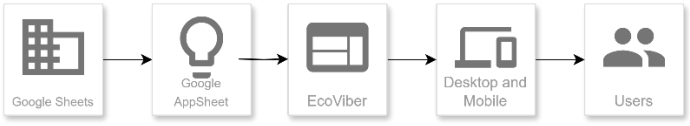


Figure 3. Database structure and framework compatibility for EcoViber application

The EcoViber development process leverages a Google Sheets database and the Google AppSheet editor. Google AppSheet, a Low Code development platform [25], enables efficient creation of applications for both web and mobile platforms. This setup is illustrated in Figure 4.

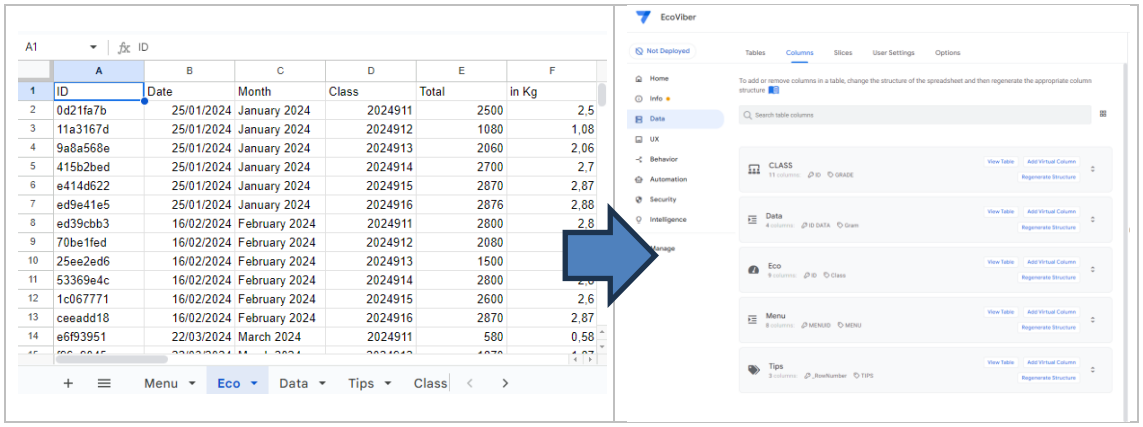


Figure 4. EcoViber application development process

There are four main menus in its development: EcoViber, Tips, Admin, and Login/Logout, as shown in Figure 5.

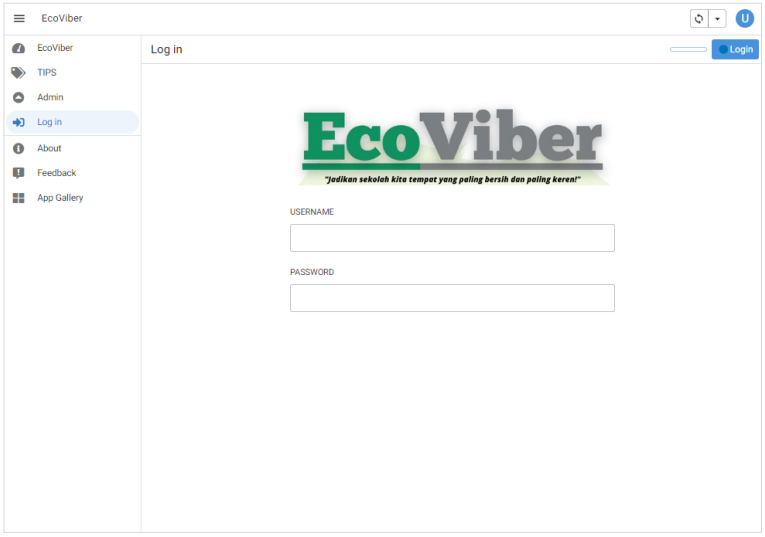


Figure 5. Main menus in the Ecoviber application

EcoViber menu displays the amount of plastic waste collected by each class from grades 1 to 6. The data is sorted so that the class with the most plastic waste collected appears at the top, ranked in descending order, as illustrated in Figure 6. Additionally, the Tips menu provides education on the negative impacts of plastic waste and offers guidance on proper plastic waste management. The goal is to help users understand the importance of managing plastic waste correctly and to implement practices that reduce its environmental impact. Through this menu, users are expected to gain valuable information and learn practical steps for managing plastic waste in their daily lives.

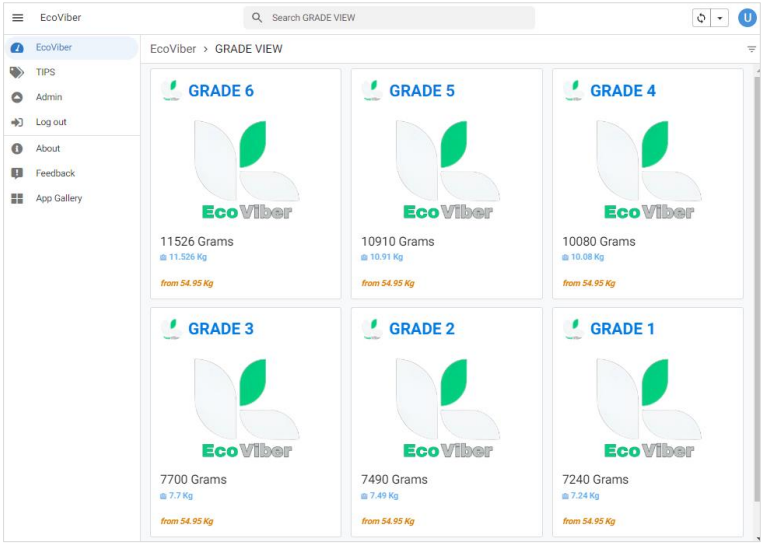


Figure 6. Plastic waste collection rankings and tips for proper waste management in the EcoViber application

Admin menu, where authorized users can log in to enter the weight data of weighed plastic waste, as shown in Figure 7. Access is restricted to administrators, including a designated teacher and two student representatives from each class. Usernames and passwords will be regularly updated to maintain data security and integrity. The input form includes several required fields: current date, class name, waste amount in grams, total waste amount in grams, and an automatic conversion to kilograms. This menu enables administrators to efficiently input and manage collected plastic waste data, ensuring accuracy and consistency in reporting.

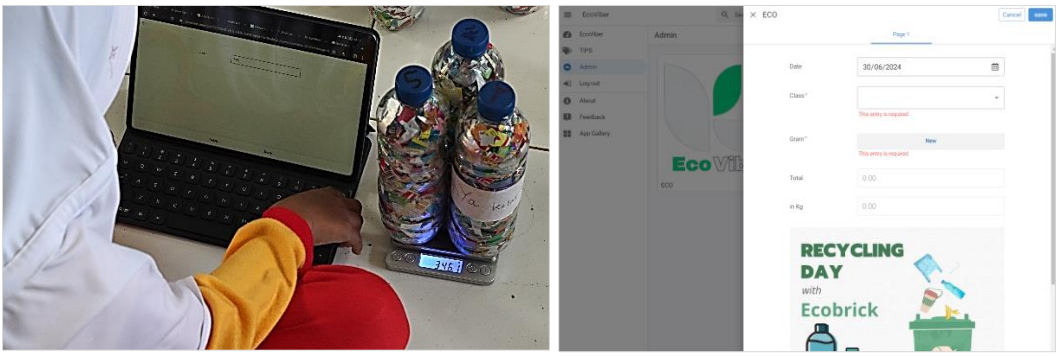


Figure 7. Plastic waste data input form in the Admin menu of the EcoViber application

The total weight data of plastic that has been inputted will be visualized in the form of graphs and detailed reports per class, as shown in Figure 8. This visualization allows for easier monitoring and provides a clear overview of the amount of plastic waste collected in each class, as well as collection trends over time. With these graphs and reports, users can analyze data more effectively and understand each class's contribution to plastic waste management efforts.

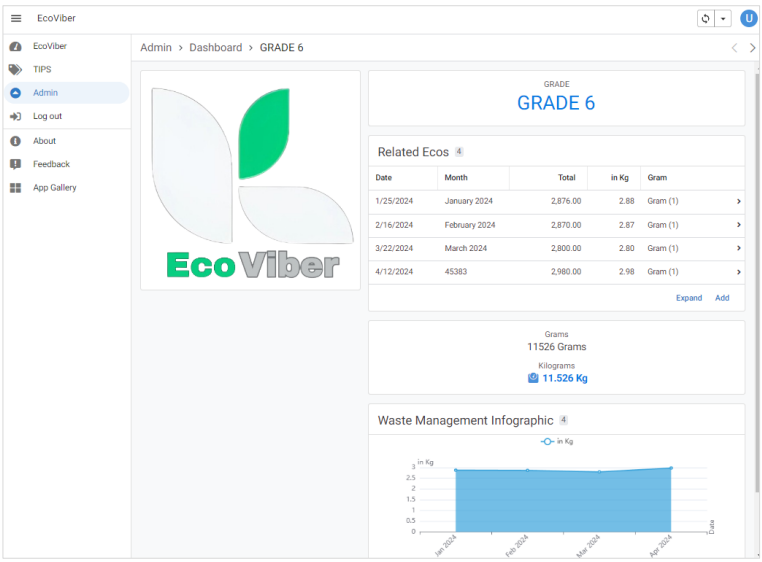


Figure 8. Visualization of plastic waste weight data in graph and class reports

During the application testing period from January to April 2024, teachers and students from grades I to VI actively participated in the collection of plastic waste in ecobrick form, totaling approximately 54.95 kg. This includes 14.09 kg collected in January, 14.65 kg in February, 11.14 kg in March, and 15.07 kg in April, as illustrated in Figure 9. The data collection process involved using EcoViber to record the weight of plastic waste collected each month, utilizing a weighing scale integrated into the application.

The types of data collected included the monthly weight of plastic waste in kilograms, categorized by ecobrick collection. This data was visualized using EcoViber's reporting and graphing features, which provided detailed insights into the amount of plastic waste accumulated over time.

Educational components integrated into the app included environmental tips and articles aimed at increasing awareness of waste management practices among students. These educational resources supplemented the practical aspects of waste collection by fostering a deeper understanding of environmental sustainability and encouraging responsible waste disposal habits. The success of this initiative highlights significant progress in promoting cleanliness and sustainability within the school environment, driven by active engagement and commitment from both teachers and students.

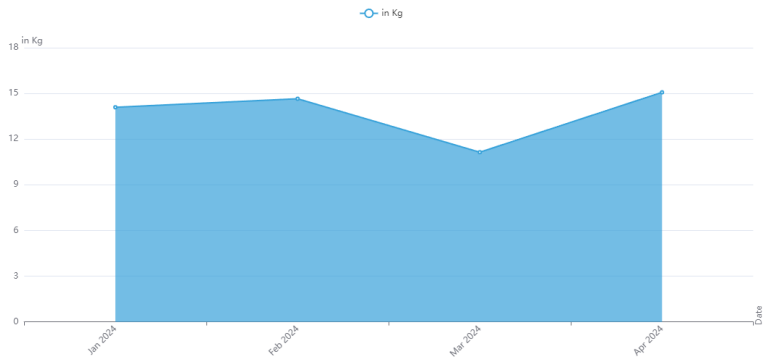
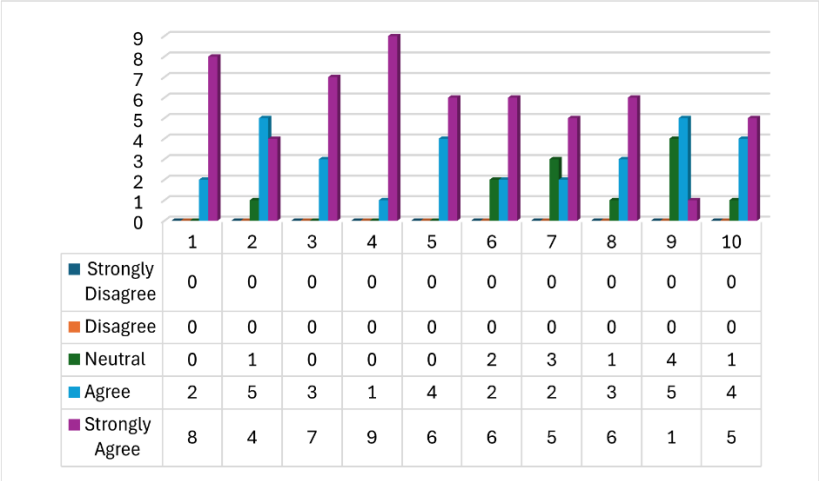


Figure 9. Monthly plastic waste collection using EcoViber

3.3. User Satisfaction

The findings from the EcoViber application questionnaire highlight positive user feedback in key areas, as illustrated in Figure 8. Users found the application easy to navigate, with a majority rating it very user-friendly. The interface design was generally considered intuitive, especially by those who found it visually

appealing. Visual guides for plastic waste management were well-received, significantly aiding users. Features such as plastic waste recording and informational reports and graphs were also praised for their ease of use and their effectiveness in presenting data. Overall, respondents expressed satisfaction with EcoViber, emphasizing its usability, helpful features, and motivational impact on environmental awareness and cleanliness efforts. Following successful testing, the system is deployed for operational use. Regular maintenance activities are crucial to sustain its performance, while ongoing enhancements to optimize user experience and functionality are prioritized.



	1	2	3	4	5	6	7	8	9	10
Strongly Disagree	0	0	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0	0	0
Neutral	0	1	0	0	0	2	3	1	4	1
Agree	2	5	3	1	4	2	2	3	5	4
Strongly Agree	8	4	7	9	6	6	5	6	1	5

Figure 10. EcoViber application feedback summary

An explanation of the results and in-depth analysis based on the EcoViber application's development and implementation at SDN Perdopo 02 reveals significant improvements in plastic waste management within school environments. Through comprehensive observations and interviews with seven teachers, EcoViber effectively addresses the longstanding issue of plastic waste accumulation. The application's user-friendly interface and intuitive design facilitate easy recording and monitoring of plastic waste data, promoting transparency and accountability among school administrators and students alike. Visualizations such as graphs and detailed reports provide clear insights into waste accumulation trends across different classes, enhancing monitoring capabilities and fostering a culture of environmental stewardship.

Comparison of these findings with existing studies underscores the transformative potential of technological solutions like EcoViber in different settings. Similar innovations, such as smart dustbins and IoT-based technology [26], have proven successful in optimizing waste management practices globally. Additionally, NEXA, a smart mobile management system, has effectively reduced plastic waste from hotel room key cards [27]. Furthermore, an application likes FoodSaveShare has shown significant potential in decreasing household food waste [28].

EcoViber contributes to these achievements by offering practical tools for data-driven decision-making and educational outreach in plastic waste management. By empowering users with actionable insights and features such as tips on plastic waste management, recording plastic waste data, informative reports, and graphical representations, along with a ranking system that motivates students to collect plastic waste more effectively, EcoViber enhances operational efficiency and cultivates a deeper understanding of environmental impacts among teachers, students, and other school community members.

Despite the advancements made, the study acknowledges several limitations that could potentially impact the validity of its findings. One significant limitation is the potential for bias in data reporting, which hinges on accurate and consistent data entry by administrators. Variations in data handling practices or subjective interpretations of waste measurements could introduce inconsistencies and affect the reliability

of the collected data. Furthermore, the study's narrow focus on a single school environment may restrict the generalizability of its results to broader educational contexts with diverse infrastructural or operational challenges.

To address these limitations in future research, specific methods and approaches can be implemented. Firstly, conducting multi-site studies across various school environments, even involves challenges like managing geographic distances and ensuring effective communication [29], can offer a more comprehensive understanding of EcoViber's effectiveness and applicability across different settings. This approach allows researchers to account for variations in infrastructure and operational practices, thereby enhancing the study's external validity. Secondly, employing a mixed-methods approach that combines quantitative metrics on waste management with qualitative insights from stakeholders [30], [31] can enrich the study's findings and provide deeper insights into EcoViber's impact and user perceptions.

EcoViber application represents a pivotal step towards sustainable plastic waste management in schools. By leveraging technology to streamline data collection, analysis, and educational outreach, EcoViber not only supports operational efficiency but also fosters a culture of environmental responsibility among school communities. Addressing identified limitations and further exploring the application's scalability and long-term impacts will be essential for maximizing its effectiveness and sustainability in promoting clean, healthy, and eco-conscious school environments.

4. CONCLUSION

The development and implementation of the EcoViber application represent a significant advancement in addressing the critical challenge of plastic waste management within school environments. By offering a user-friendly interface for recording and monitoring waste data, EcoViber effectively streamlines processes and encourages active participation in environmental stewardship. The research findings underscore the transformative role of technology in promoting sustainability and cultivating a culture of eco-consciousness among students and educators alike. However, limitations such as potential biases in data reporting and the focus on a single school environment may affect the broader applicability of the findings. Future research should explore EcoViber's effectiveness across diverse educational contexts and refine methodologies to enhance scalability. Beyond optimizing waste management practices, EcoViber serves as a catalyst for fostering cleaner, healthier, and more sustainable school environments. Through its integration of practical tools and educational components, EcoViber not only enhances operational efficiency but also deepens understanding of environmental responsibility. This innovative approach sets a new benchmark for waste management in schools, inspiring future generations to adopt eco-friendly behaviors and contribute actively to a greener, more sustainable world.

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