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MAKE-ROSCOPE: Accuracy and Practicability of Commercially-Available Keychain Microscope

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Abstract

Microscopy is an integral and fundamental skill in medical technology/medical laboratory science (MT/MLS) education, particularly practiced peripheral blood smears (PBS) analysis. This study evaluated the commercially available keychain microscope's accuracy, practicability, and effectiveness for potential use in educational settings. A mixed-methods research design was utilized, involving 50 licensed professionals (48 Registered Medical Technologists and 2 Pathologists) from the Municipal Health Units of Bacnotan, Balaoan, Bangar, City of San Fernando, Luna, San Gabriel, San Juan, Santol, and Santo Domingo, Ilocos Sur, as well as from La Union Medical Diagnostic Center and Hospital, Inc. (LUMED), the Philippine National Police (PNP) – Vigan City, and Metro Vigan Cooperative Hospital.

Participants assessed the same PBS sample using both the commercially available keychain microscope and a traditional compound microscope. Results showed that while the keychain microscope was significantly less accurate in visualizing cell morphology ($p < 0.05$), it was rated highly for practicability, especially for ease of use and portability. However, effectiveness in terms of image contrast, sharpness, and structural visibility was considerably lower than that of the traditional microscope. The traditional compound microscope remains the preferred tool for precise cell analysis, which indicates there is a statistically significant difference in favor of the traditional compound microscope in terms of accuracy and effectiveness. Thus, while the keychain microscope serves as a low-cost, accessible option for introductory microscopy instruction, it is best used as a supplementary tool in school-based laboratory education.

Keywords: Keychain Microscope, Peripheral Blood Smear, Accuracy, Practicability and Effectiveness

1. Introduction

In biological and material sciences, microscopy is essential for students, researchers, and educators, as it allows them to envision structures at the microscopic level. Microscopy refers to the study and use of microscopes to observe objects and structures that are too small to be seen with the naked eye. Different types of microscopes, such as light microscopes, electron microscopes, and scanning electron microscopes, are used to explore various aspects of the microscopic world. The microscope has revolutionized numerous fields by revealing the cellular foundation of life, improving medical diagnostics, and enabling the study of microscopic life forms, plant tissues, and animal cells. It has accelerated progress in disciplines such as anatomy and histology, becoming a valuable tool for students, pathologists, and researchers, and has had a substantial impact on public health (Chanda, 2024).

The application of microscopy extends beyond research to include quality control, forensics, and environmental science. It permits researchers to identify structural weak points in materials, examine traces of evidence in forensic investigations, and detect hazardous microorganisms in air and water. According to Gellisch et al. (2025), microscopy is essential for identifying diseases, as it reveals cellular and tissue abnormalities that conventional approaches cannot detect [1]. In educational settings, microscopy also serves as a bridge between theoretical knowledge and practical observation, allowing students to examine cells, tissues, and microscopic organisms closely. Its ability to illuminate the invisible world makes it essential for scientific discovery, technological advancement, and practical problem-solving across various disciplines. Thus, microscopy remains a cornerstone of modern science and a versatile technology with wide-ranging applications.

According to Excedr (2024), microscopy is a powerful scientific technique used to magnify small objects not visible to the naked eye, enabling scientists to study the intricate details of cells, tissues, and microorganisms [2]. It is crucial in various fields, including biology, medicine, and material science. In medical research and diagnostics, microscopy is essential for identifying pathogens, examining tissue samples, and detecting cellular abnormalities that may indicate disease. This technique is particularly valuable in microbiology and pathology, where it aids in diagnosing infections and conditions such as cancer, as well as monitoring the effectiveness of treatments. The microscope's ability to reveal fine details contributes to advancements in various scientific research areas by providing clear, detailed images supporting both qualitative and quantitative analysis.

Most brands of traditional compound microscopes available on the market offer models at varying price points depending on their features and intended applications. Well-known manufacturers include Zeiss, Nikon, and Olympus. In this regard, Olympus manufactures the high-quality CX23 compound microscope, which is frequently utilized in laboratories and classrooms. In online shops like Microscope Central, the price of these microscopes, starting at ₱50,000 or more, is often expensive for many educational institutions. Zeiss and Nikon models, including the Zeiss Primostar and the Nikon Eclipse series, range in price from ₱80,000 to over ₱200,000, depending on the features. Hence, traditional compound microscopes are an expensive purchase, particularly for schools with limited resources [3].

Commercially available keychain microscope kits, on the other hand, such as those offered on platforms like Shopee and TikTok shops, provide a more accessible an inexpensive alternative for simple instructional purposes. Depending on the accessories and features of the kit, these kits usually cost between ₱199 and ₱2,000. For approximately ₱199 to ₱550, kits such as the Make-roscope by Jeremy de Leon, a low-cost, portable keychain microscope that can be mounted on the front camera of any smartphone or tablet and magnify organisms from 100x to 400x, are also offered. These kits are excellent for fieldwork and educational purposes because they are more portable than traditional compound microscopes and are easily accessible online [4].

Regarding accessibility and convenience, commercially available keychain microscope kits are typically simpler to transport and store. Unlike traditional compound microscopes, which need to be handled carefully and stored in designated areas due to their size, keychain microscopes can be utilized in various settings because of their smaller, lighter design. With over 12 million Filipino students using compound light microscopes annually, the Make-roscope offers an alternative. "Kits," which include prepared specimen slides and sample collection tools like pipettes, tweezers, tubes, and among others are introduced and integrated with the Make-roscope. At the time, the keychain microscope was being used by more than 8,500 Filipino teachers and students. Moreover, Make-roscope by Jeremy de Leon, available on Shopee and TikTok Shop, are utilized in this study to compare traditional compound microscope and commercially available keychain microscope kits regarding its accuracy, practicability, and effectiveness in educational settings.

The Make-roscope is a commercially available keychain microscope designed to attach to smartphones and tablets. Its small size allows students and educators to carry it as a keychain, promoting on-the-go learning. Unlike traditional compound microscopes, the Make-roscope offers accessibility and convenience. Its single-lens design is easily mounted on a device's front-facing camera, ensuring practical and ergonomic use. While its color options are not specified, it likely follows a minimalist, student-friendly aesthetic. Usability is a key feature, requiring minimal setup to achieve magnification. Although initial use presents a slight learning curve, users quickly adapt with magnification ranging from 265x to 400x—comparable to school-grade compound microscopes—the Make-roscope enables students to observe microscopic details of cells and tissues. Using smartphone cameras provides clear, high-resolution images and offers an affordable, portable alternative to traditional compound microscopes. This enables access to microscopy, supporting hands-on, experiential learning, particularly in resource-limited educational settings [5].

Furthermore, commercially available keychain microscope kits offer a practical and affordable solution for integrating hands-on microscopy into classrooms. These kits include essential accessories and instructional materials, making them ideal for beginners and students seeking a more accessible way to explore life sciences. They are created and marketed for educational purposes, particularly for beginners and students, offering a cheaper and more accessible alternative while providing a hands-on experience with microscopy. Commercially available keychain microscope kits significantly enhance practical learning opportunities in resource-limited settings.

These kits provide an accessible means for students to engage with hands-on scientific inquiry, bridging the gap between theoretical concepts and practical application in the classroom (UNESCO, 2024) [6]. The key benefits of these commercially available keychain microscope kits are their user-friendly design, simple setup, and low cost, which make them especially useful for under-resourced institutions. Recent developments in optical technology enable these kits to provide high-quality imaging at a lower cost, making them appropriate for instructional purposes. However, compared to traditional compound microscopes, they are not always as precise or durable. Still, their true strength lies in affordability and ease of use, making them accessible to many students. These kits significantly impact classrooms worldwide, offering hands-on experiences that bring science to life and spark curiosity [7].

According to UNESCO (2022), integrating portable and commercially available keychain microscope kits has been particularly beneficial in under-resourced regions with limited access to traditional laboratory equipment [8]. A study conducted by Williams et al. (2020) highlights that these kits enhance students' understanding of microscopic concepts in countries where educational institutions face financial constraints, enabling students to gain practical experience without the high costs of standard laboratory equipment [9]. Furthermore, technological advancements in microscope kit design, such as developing digital and mobile-compatible microscopes, broaden the accessibility of scientific tools in classrooms globally [10].

In settings with limited resources, low-cost smartphone-based microscopes offer significant advantages, as reviewed by Salido et al. (2022) [11]. These microscopes use clip-on lenses and smartphone cameras to increase magnification and image resolution, making them ideal for field research and education in budget-constrained environments. The integration of fluorescence imaging capabilities further enhances their utility for scientific exploration. Although they do not match the advanced features of traditional, high-cost microscopes, these affordable tools provide valuable microscopy experiences, especially for students and researchers in low-resource settings, fostering scientific engagement and education. One notable disadvantage of this setup is that the quality of the results heavily depends on the smartphone's camera. If the device has a low-resolution or outdated camera, it may produce blurry or unclear images, affecting the accuracy and reliability of the analysis.

In addition, the BioBus DIY microscope kit is designed as a hands-on material that allows students to design and create their own microscopes. The 3D-printed designs of the DIY microscope are customized to create a functional microscope, offering students a more accessible and affordable alternative to traditional compound microscope. The DIY microscope kit is developed as an educational tool, providing both high-quality and low-cost options. Over 230 students explore optics and advanced techniques through this kit, promoting cross-disciplinary learning by mimicking human vision. In areas with limited resources, the paper-based Foldscope microscope demonstrates its potential for diagnosing urinary tract and oral infections [12].

Another study by Kaur et al. (2020) finds that the Foldscope can accurately identify microorganisms. Recent advancements in digital image processing, computer vision, and open hardware/software make microscopy more accessible and affordable, with tools like OpenCV, Scikit-learn, and Fiji/ImageJ driving innovation [13]. Low-cost 3D printing and telecommunications enable telemicroscopy and mobile diagnostic devices, transforming microscopy into a more widely available and cost-effective solution for education and clinical use. The field of microscopy has witnessed significant advancements in recent years, driven by the need for accessible and affordable solutions. Educators embrace DIY approaches, such as creating microscope camera adapters, to upgrade existing equipment and enhance student learning [14]. Digital microscopes also gain popularity in educational settings, fostering collaborative learning environments and enabling students to capture high-resolution images for analysis [15].

In healthcare, researchers develop innovative smartphone-connected microscopes that can be used for telemedicine, particularly in remote or resource-limited areas. These devices often employ readily available components and provide a convenient way to share images and videos for diagnosis and consultation. Furthermore, advancements in 3D printing technology lead to the creation of low-cost microscopy platforms like the FPscope, which offers high-resolution imaging capabilities suitable for educational and research purposes [16]. These innovations collectively demonstrate the potential for affordable microscopy solutions to address challenges in various fields, including education, healthcare, and scientific research.

The OpenFlexure Microscope is an open-source, 3D-printed device that has gained international recognition for its affordability and accessibility in education and research. Developed to provide high-quality microscopy on a budget, this design integrates webcam optics or lab-grade objectives, making it ideal for low-resource settings [17]. It plays a role in democratizing access to microscopy in schools, particularly in underdeveloped regions, by significantly reducing the costs associated with traditional compound microscopes. Moreover, the OpenFlexure project facilitates advancements in precision imaging through its motorized control feature, which allows for accurate sample analysis in various scientific applications [18].

A pilot program in Tanzania utilizes the OpenFlexure Microscope in biology classrooms, demonstrating that the tool enhances students' hands-on learning experiences. By incorporating 3D printing and open-source technology, the OpenFlexure Microscope aligns with global efforts to improve science education through accessible and scalable innovations, making it an ideal solution for schools and laboratories facing resource constraints [19].

Schaefer et al. (2023) discussed the development of a low-cost smartphone fluorescence microscope designed for research, life science education, and STEM outreach [20]. This innovative tool enhanced accessibility to microscopy by integrating affordable technology, making it ideal for educational settings. They emphasized that such devices could significantly improve hands-on learning experiences in biology and promote engagement in scientific inquiry among students. This aligned with the need for accessible laboratory equipment to facilitate practical education in resource-limited environments.

In the Philippines, proficiency in microscopy is a cornerstone of Medical Laboratory Science (MLS) education, as outlined in the Commission on Higher Education's (CHED) CMO No. 14 Series of 2006 [21]. This memorandum emphasized the importance of equipping students with the necessary skills to conduct detailed microscopic examinations, identify microorganisms, and utilize microscopy techniques in clinical diagnosis. These competencies were integral to the accuracy and reliability of aboratory results, directly impacting patient care and clinical outcomes. Therefore, hands-on training in microscopy was a crucial component of MLS curricula, ensuring that graduates were proficient in performing diagnostic procedures and contributing effectively to healthcare delivery.

Commission on Higher Education Memorandum Order No. 6 (2017) focused on expanding the guidelines for the CHED Research Chair Award, clarifying eligibility and procedures for faculty and researchers in higher education institutions [22]. It outlined the award's coverage, eligibility requirements for project leaders, and the nomination process. Moreover, CHED Memorandum Order No. 17 (2017) provided updated policies for the undergraduate programs in Medical Laboratory Science, emphasizing outcomes such as competency in various laboratory techniques, including proficiency in microscopy, to enhance clinical practice [23].

Make-roscope, a commercially available keychain microscope, was highlighted as innovative educational tools that enabled students to explore the microscopic world. These portable microscopes effectively magnified specimens, making science accessible and engaging. The initiative fostered curiosity and enhanced science education by integrating practical tools into students' daily lives [24].

Furthermore, Reyes et al. (2024) noted that technological advancements have increased the number of commercially available keychain microscope kits, making them beneficial for educational institutions to enhance experiential learning [25]. However, these microscope kits raise questions about their suitability for more advanced academic contexts. Often used for recreational purposes, they allow individuals to explore microscopic images to feed their curiosity. Additionally, some use them in educational environments due to their affordability and ease of access. While these kits are mainly designed for introductory-level instruction, they do not always meet the accuracy and quality standards necessary for specialized programs. Nevertheless, it helps students observe fundamental slides, such as peripheral blood smears, under commercially available keychain microscope kits.

The Make-roscope, a commercially available keychain microscope created by Jeremy de Leon, efficiently addressed access and price hurdles in scientific education in developing countries like the Philippines. The Make-roscope was funded by the Technology Application and Promotion Institute (DOST-TAPI) under the Invention-Based Enterprise Development (IBED) Program, and it reached over 8,500 Filipino students and instructors, considerably improving their learning experiences [26].

Moreover, the Invention-Based Enterprise Development (IBED) Program supported the introduction of Make-roscope to schools, organizations, and institutions in Luzon, Visayas, and Mindanao. Its value increased during the COVID-19 pandemic, as it allowed students to engage in hands-on microscopy despite the constraints of online learning, which mainly depended on videos and simulations [27]. In addition to educational kits containing prepared slides and sample collection tools, the Make-roscope promotes active learning, which was shown to improve student engagement and academic outcomes [28]. Overall, the Make-roscope represented a significant improvement in inexpensive microscopy, empowering students and educators by making science education more accessible and engaging and transforming teaching approaches in various contexts (Rodríguez & Hernández, 2022).

The study by Calvo-Haro et al. (2021) explored the use of 3D printing for creating medical devices, including microscopes, at a university hospital [29]. They demonstrated that 3D-printed microscopes could be produced cost-effectively and rapidly, offering a practical solution for diagnostic needs. The flexibility of the 3D printing process allowed for the customization of the microscope's design to meet specific laboratory requirements. This innovation aimed to improve access to diagnostic tools in resource-limited settings by reducing costs and reliance on traditional manufacturing and supply chains.

Integrating commercially available keychain microscope kits in educational settings, particularly for science, technology, engineering, and mathematics (STEM) education, gained attention. Accessible microscopy solutions, like the Make-roscope keychain, offered significant benefits for students, especially in resource-constrained environments. The portability and affordability of the kits made them an attractive option for schools aiming to enhance hands-on learning experiences, fostering curiosity and understanding in students . The Make-roscope kit exemplified how microscopy innovations addressed STEM education gaps, making practical laboratory experiences more inclusive and widespread. The role of practical laboratory experiences in science education was crucial for developing students' competencies and interest in STEM fields.

This study aimed to evaluate the accuracy, practicability, and effectiveness of commercially available keychain microscope kits in school-based training laboratories, particularly for basic instructional activities such as peripheral blood smear (PBS) analysis. The study focused on evaluating the accuracy of each microscope in terms of the clarity in color, shape, and stain (Wright stain). Additionally, the study evaluated the practicability of commercially available keychain microscopes in educational settings by assessing ease of use, portability, and cost-effectiveness. Moreover, the study evaluated the level of effectiveness of each microscope in consideration of its contrast, sharpness, and structural visibility.

The results of this study were beneficial to the field of medical technology/medical laboratory science (MT/MLS) education, particularly for students' hands-on learning. If proven feasible, it offered a more affordable and convenient option for school-based laboratories without replacing traditional compound microscopes. Moreover, administrators could utilize the findings to make informed resource allocation decisions, addressing budget constraints while maintaining educational quality. This study generally fostered innovation in MLS education, bridging the gap between underfunded and well-funded institutions, and ensuring that students were better equipped for clinical work, benefiting the overall quality of education in the healthcare system.

This study did not attempt to replace traditional, high-quality microscopes used in clinical or diagnostic laboratories, as the comparison would have been distinctly inequitable and biased. Instead, it aimed to explore the feasibility and potential use of these microscope kits for educational and training purposes. Although it might not have been entirely applicable for the professional use of microscopes in hospitals or clinical settings, it can be useful for school-based training laboratories where traditional, high-quality microscopes were unavailable.

1.1 Objectives

This study aimed to evaluate the accuracy, practicability, and effectiveness of commercially-available keychain microscopes in assessing cell morphology, particularly in the context of peripheral blood smear (PBS) analysis in educational settings. Specifically, the study sought to address the following questions:

1. What is the level of accuracy in cell morphology assessment in both the control and experimental groups with respect to the clarity of cell morphology in terms of:

a) Color;

b) Shape; and

c) Stain (Wright Stain)?

2. What is the perceived level of practicability of commercially-available keychain microscope in educational settings in terms of:

a) Ease of use;

b) Portability; and

c) Cost-effectiveness?

3. What is the level of effectiveness of microscopes in educational settings in both control and experimental groups in terms of:

a) Contrast;

b) Sharpness; and

c) Structural Visibility?

4. Is there a significant difference between the grade of experimental group and control group when assessed according to:

a) Level of accuracy of cell morphology assessment; and

b) Level of effectiveness of microscopes?

2. Materials and Methods

To effectively collect and analyze the necessary data for evaluating the accuracy, practicability, and effectiveness of the commercially available keychain microscope, the researchers utilized a combination of structured instruments aligned with the mixed-methods design of the study. Data were analyzed using descriptive statistics to interpret scores on accuracy, resolution, and practicability. The study employed a structured observation checklist and a 4-point Likert scale to measure the accuracy of the keychain microscope in visualizing peripheral blood smear (PBS) sample features such as color, shape, and stain (Wright Stain). For the assessment of effectiveness, a resolution test was utilized, focusing on contrast, sharpness, and structural visibility.

The perceived practicability of the microscope kits in educational settings was evaluated using a survey with items on ease of use, portability, and cost-effectiveness, with each item rated on a 4-point scale ranging from “Not Practical” to “Highly Practical.” To ensure the instrument’s relevance and rationality, it underwent validation by five expert professionals with extensive backgrounds in medical technology/medical laboratory science and demonstrated competency in microscopy. The instrument was pre-tested on thirty (30) registered medical technologists and pathologists working in various healthcare settings to identify ambiguities or areas requiring clarification, allowing for necessary modifications before the primary data collection phase.

2.1 Data Gathering Procedure

The data gathering procedure, as illustrated in Figure 1 page 11, was conducted systematically to ensure the accuracy and reliability of results while strictly adhering to ethical standards. Two groups were prepared: one using a commercially-available keychain microscope (experimental group) and the other using a traditional compound microscope (control group). To maintain consistency in assessment, only one peripheral blood smear (PBS) sample was prepared and presented to both groups. The study was anchored in fundamental ethical principles, including voluntary participation, the right to withdraw, anonymity, confidentiality, and non-maleficence. Participants were fully informed of the study’s purpose, procedures, and any potential risks before data collection. Informed consent was obtained from each participant, ensuring that their involvement was voluntary and free from coercion.

Anonymity was preserved by ensuring that no personally identifiable information was collected or linked to responses. All data were treated with strict confidentiality and used solely for academic purposes. Access was restricted to the research team, and all records were securely stored to prevent unauthorized access or disclosure.

To uphold the principle of non-maleficence, the study was designed to avoid causing any form of physical, emotional, or psychological harm. All procedures were conducted professionally and sensitively, prioritizing the safety, dignity, and welfare of participants. Moreover, participants were reminded of their right to withdraw from the study at any point without penalty or the need to provide justification.

Prior to data collection, the research protocol underwent a formal review by the LORMA Colleges Research Ethics Committee

(REC). The committee evaluated all aspects of the study—including its objectives, methodology, data protection strategies, and ethical safeguards—before issuing ethical clearance, thereby ensuring compliance with institutional and national research standards.

Following ethics approval, preliminary steps included sending formal communication to the research adviser, research statistician, and Dean for guidance and administrative approval. Participants were recruited through official invitation letters that clearly outlined the study's purpose, procedures, and ethical protections. Informed consent was reaffirmed before participation began.

As part of the preparation phase, the procurement of Make-roscope kits was carried out. These commercially-available keychain microscopes were purchased from the Shopee store jereMake at ₱549.00 per unit. The kits were chosen for their affordability, simplicity, and usability in resource-limited educational environments. Each kit included essential microscopy tools and was designed for smartphone integration, providing magnification ranging from 100x to 400x—suitable for observing cellular morphology in PBS analysis.

For specimen collection, a single third-year Medical Laboratory Science student served as the blood donor to ensure consistency across all test samples. The donor underwent a complete medical evaluation, including laboratory tests such as CBC, hemoglobin, hematocrit, and platelet count. Medical clearance was issued by a licensed physician. Under the supervision of a registered medical technologist (RMT), 5 mL of venous blood was drawn using sterile techniques. The donor provided informed consent, and all ethical standards regarding specimen handling, anonymity, and voluntary participation were strictly observed.

Peripheral blood smears were prepared following standard laboratory protocols. Researchers used clean slides, Wright staining reagents, and maintained proper technique to ensure consistent sample quality. Slides were labeled, smeared, stained, and dried according to accepted procedures. Quality assurance was observed throughout, with oversight from a licensed RMT to ensure laboratory standards and internal validity.

During the microscopy phase, participants examined the same PBS sample using their assigned microscopes. With the keychain microscope, the slide was placed on the lens and viewed using a smartphone camera. With the compound microscope, the slide was placed on the stage and observed under low-power objective. Participants evaluated the clarity of the cell morphology in terms of color, shape, and stain quality. They then completed a structured survey assessing the usability, portability, and cost-effectiveness of the keychain microscope.

Additionally, a resolution test was conducted to evaluate contrast, sharpness, and structural visibility. Observational notes were recorded throughout the process to document participant behavior, challenges encountered, and any issues related to microscope usability. These qualitative observations supported and contextualized the survey data.

For data analysis, the study employed both descriptive and inferential statistics. Weighted means were computed to assess responses related to practicability and effectiveness. An independent t-test was used to determine if significant differences existed between the control and experimental groups regarding clarity and usability. All data were encoded and processed using Python and Microsoft Excel. Observational data were thematically analyzed to identify trends and patterns, enhancing the depth of interpretation.

This mixed-methods approach ensured that the study's findings were robust, valid, and aligned with its objectives, providing meaningful insights into the educational applicability of commercially-available keychain microscopes in resource-limited academic settings.

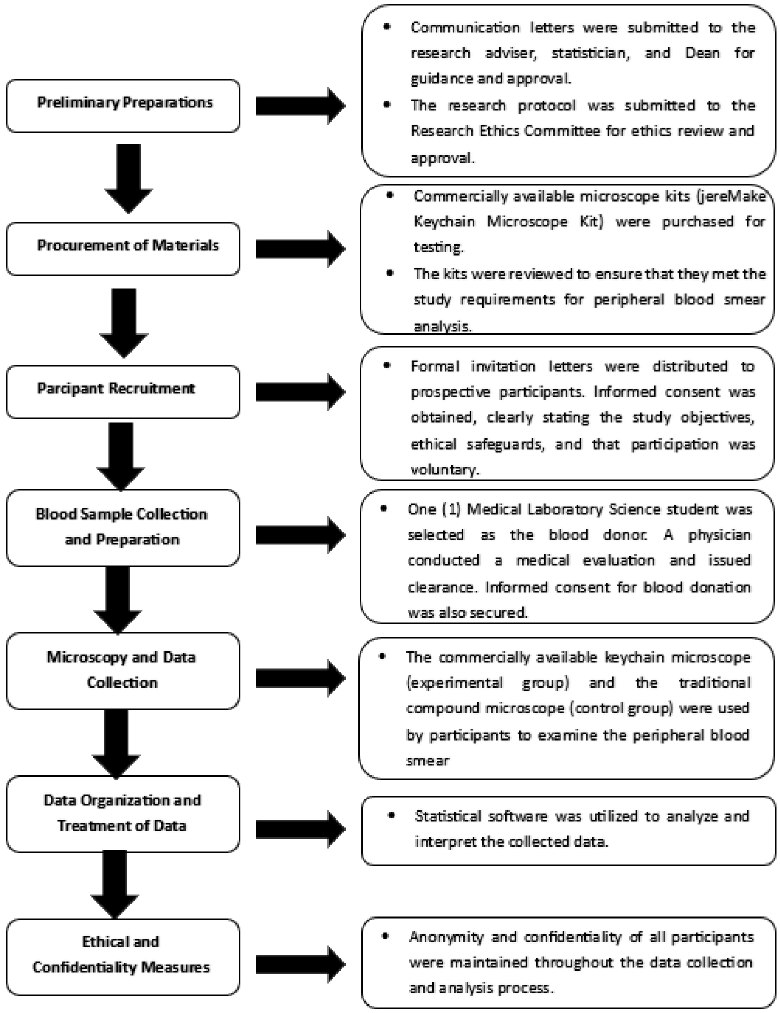

Figure 1: The Data Gathering Procedure of the Study

4. Results

Level of Accuracy of Cell Morphology Assessment in Terms of the Clarity of Cell Morphology

Group	Mean Score	Descriptive Equivalent	Interpretation
Experimental Group (Commercially available keychain microscope)	2.74	Moderately Clear and Accurate	Blood cells are visible. Shape, color, and stain are slightly distorted. Identification is possible with effort.
Control Group (Traditional compound microscope)	3.99	Highly Clear and Accurate	Blood cells are clear and accurately displayed with proper color, shape, and stain.

Table 1: Mean Score of the Level of Accuracy of Cell Morphology Assessment in Both Control and Experimental Groups
Legend: 3.26-4.00 - Highly clear and accurate, 2.51-3.25 - Moderately clear and accurate, 1.76-2.50 - Slightly clear and accurate, 1.00-1.75 - Not clear and accurate

Table 1 presented the mean scores obtained by the traditional compound microscope (control group) and the commercially available keychain microscope (experimental group) in assessing the clarity of cell morphology concerning color, shape, and stain (Wright stain). The control group achieved a mean score of 3.99, within the descriptive range of "Highly Clear and Accurate." In contrast, the experimental group recorded a mean score of 2.74, corresponding to a "Moderately Clear and Accurate" interpretation.

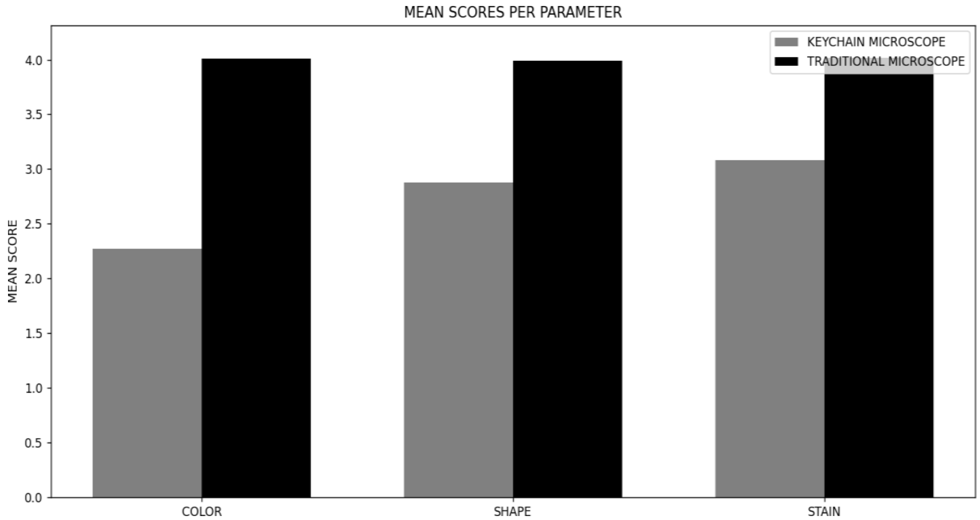

Figure 2: The Level of Accuracy of Cell Morphology Assessment in Both Control and Experimental Groups (Weighted Mean of Color, Shape, and Stain)

Parameter	T-Statistic	P-Value
Color	-15.3162	<0.001 (p < 0.05)
Shape	-10.6250	<0.001 (p < 0.05)
Stain (Wright Stain)	-10.8300	<0.001 (p < 0.05)
TOTAL	–19.3411	<0.001 (p < 0.05)

Table 2: T-Test Result of the Level of Accuracy of Cell Morphology Assessment in Both Control and Experimental Groups

Indicator: ($p < 0.05$) - there is a significant difference

To determine the statistical significance of the observed difference in accuracy between the two groups, an independent t-test was conducted. As shown in Table 2, the resulting T-statistic was –19.3411, and the p-value was <0.001, which was less than the 0.05 significance level. This indicates a statistically significant difference between the two groups' ability to assess cell morphology accurately in terms of color, shape, and stain (Wright stain).

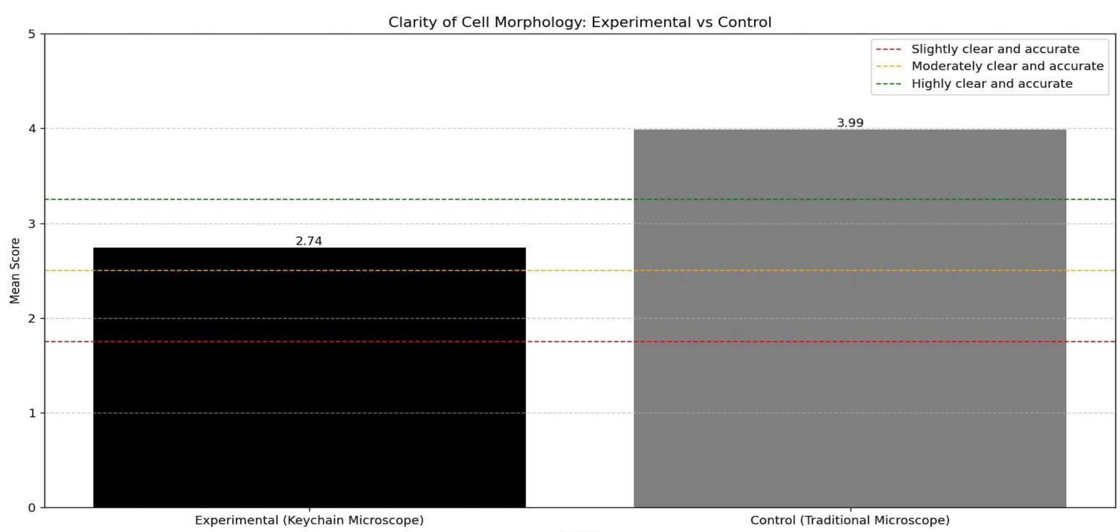

Figure 3: The Level of Accuracy of Cell Morphology Assessment in Both Control and Experimental Groups (Overall Weighted Mean)

Wan and Tao (2021) emphasized that although smartphone-based microscopes provide cost-effective and portable alternatives, they often fall short in delivering the high-resolution and optical fidelity required for detailed cellular evaluations, particularly in hematologic assessments [30]. The lack of precision in reproducing critical features—such as nuclear contour, cytoplasmic granularity, and chromatin patterns—undermines the diagnostic reliability of such tools.

Similarly, Naqvi et al. (2020) further explained that while these portable devices are helpful for initial visualization and general orientation to microscopy, they are not suitable for rigorous academic or clinical use, especially in tasks requiring accurate differentiation of cell morphology [31]. This is particularly relevant in the analysis of peripheral blood smears, where the ability to accurately interpret color intensity, cell shape, and stain distribution using Wright stain is crucial.

Perceived Level of Practicability of Commercially-Available Keychain Microscope in Educational Settings in Terms of: A) Ease of Use; B) Portability; and C) Cost-Effectiveness

Practicability Indicator	Mean Score	Descriptive Equivalent	Interpretation
Ease of Use	3.26	Highly Practical	The microscope kit is easy to use, highly portable, and cost-effective, balancing price and performance.
Portability	3.50	Highly Practical	The microscope kit is easy to use, highly portable, and cost-effective, balancing price and performance.
Cost-effectiveness	3.18	Cost-effectiveness	The microscope kit is fairly easy to use and portable, and offers a fair balance of cost and performance.

Table 3: Mean Score of the Perceived Level of Practicability of Commercially Available Keychain Microscope

Legend: 3.26-4.00 - Highly Practical, 2.51-3.25 - Moderately Practical, 1.76-2.50 - Slightly Practical, 1.00-1.75 - Not Practical

The results demonstrated that the keychain microscope achieved a mean score of 3.26 for ease of use, which is interpreted as "Highly Practical." Participants indicated that the commercially available keychain microscope was simple to operate and required minimal instruction, making it suitable for general handling, especially those without prior microscopy experience. In terms of portability, the device received the highest mean score of 3.50, also categorized as "Highly Practical." Its lightweight structure and compact design were cited as ideal for mobility, classroom demonstrations, and wide-field observation.

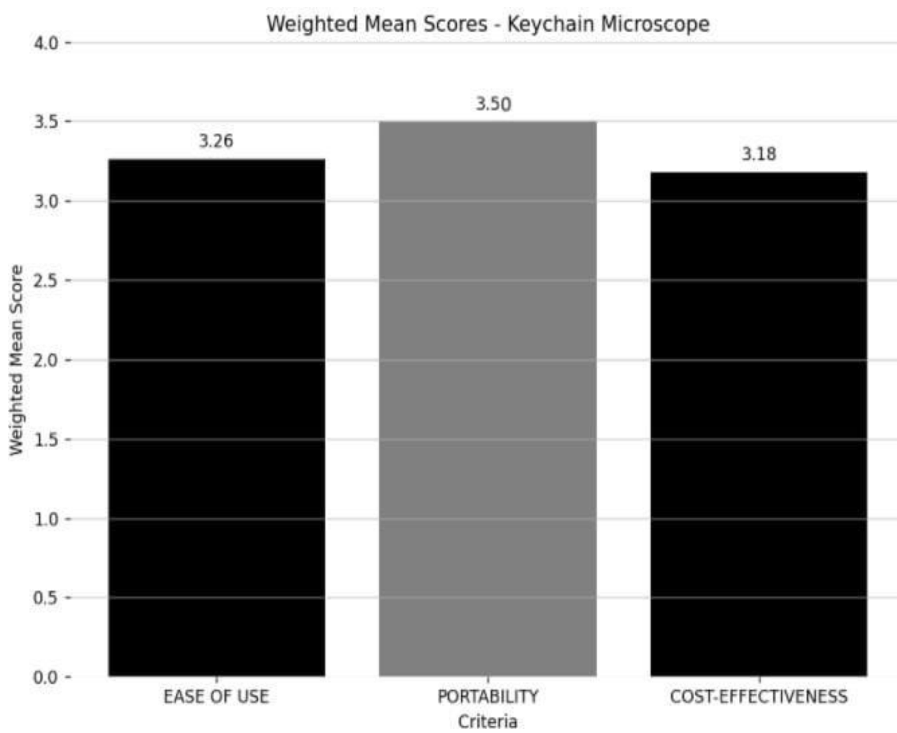

Figure 4: The Perceived Level of Practicability of Commercially Available Keychain Microscope (Weighted Mean of Ease of Use, Portability, and Cost-effectiveness

These findings are supported by Pérez et al. (2022), who noted that the Foldscope—a similarly affordable, paper-based microscope—proved to be highly practical during the COVID-19 pandemic for remote and entry-level educational use. Its simplicity, portability, and low cost made it accessible to students in resource-constrained settings, allowing them to engage with microscopy despite limitations in laboratory access. However, Pérez et al. also emphasized that while the Foldscope enhanced exposure to basic microscopy, it was not suitable for high-resolution tasks or applications requiring diagnostic accuracy. This aligns with the study's findings, where the commercially-available keychain microscope was rated highly in terms of ease of use and portability, making it an attractive tool for initial learning experiences and self-directed exploration.

Similarly, Naqvi et al. (2020) concluded that commercially-available microscopes, including smartphone-compatible models, provide foundational learning opportunities that help bridge theoretical knowledge and practical engagement. Their compact design and affordability were praised for supporting basic scientific inquiry in educational environments. However, they also cautioned that such devices lack the precision and durability required for rigorous laboratory science programs. In this context, the keychain microscope's perceived practicability—particularly its ease of use, its lightweight and mobile design, and its affordability—makes it a suitable supplementary tool for introductory education, though not a replacement for traditional compound microscope in educational laboratory settings.

Level of Effectiveness of the Microscope in Educational Settings in Both the Control and Experimental Groups in Terms of: A) Contrast; B) Sharpness; and C) Structural Visibility

Parameter	**Mean Score**	**Descriptive Equivalent**	**Interpretation**
Experimental Group (Commercially Available Keychain Microscope)	4.00	Average Performance	Acceptable level of contrast, sharpness, and structural visibility; details are discernible with some effort
Control Group (Traditional Compound Microscope)	4.00	High Performance	Excellent contrast, sharpness, and structural visibility; fine details are clearly visible and easily distinguishable

Table 4: Mean Score of the Level of Effectiveness of the Commercially available Keychain Microscope

Legend: 3.26-4.00 - High Performance, 2.51-3.25 - Average Performance, 1.76-2.50 - Below Average, 1.00-1.75 - Poor Performance

I As shown in Table 4, the traditional compound microscope obtained a mean score of 4.00, which falls within the descriptive range of "High Performance." This indicates that the device consistently provided excellent contrast, sharpness, and structural visibility—features that enabled clear identification of cellular components under microscopy. In contrast, the commercially available keychain microscope achieved a mean score of 2.53, corresponding to "Average Performance." While it allowed the observation of basic cellular features, details were discernible only with effort, likely due to limitations in magnification range, lens quality, and external lighting dependence.

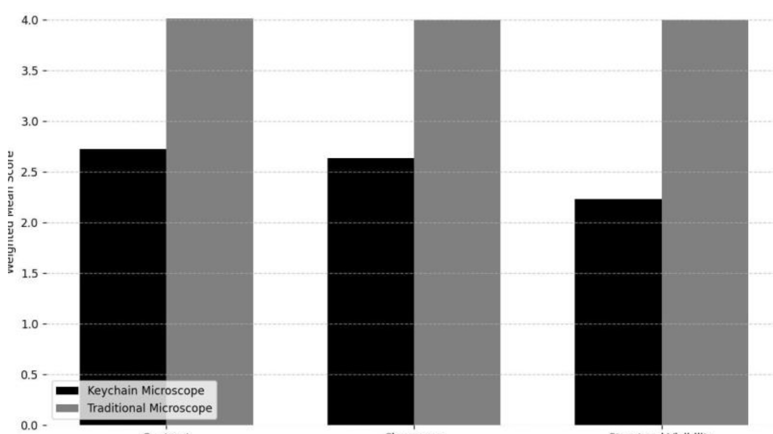

Figure 5: The Perceived Level of Effectiveness of Commercially Available Keychain Microscope (Overall Weighted Mean)

Parameter	T-Statistic	P-Value
Contrast	-15.7997	<0.001 (p < 0.05)
Sharpness	-19.8333	<0.001 (p < 0.05)
Structural Visibility	-16.4806	<0.001 (p < 0.05)
Total	-27.6642	<0.001 (p < 0.05)

Table 5: T-Test Result of The Level of Effectiveness of The Commercially Available Keychain Microscope

Indicator: ($p < 0.05$) - there is a significant difference

To statistically validate the observed difference, an independent t-test was conducted, resulting in a T-statistic of –27.6642 and a p-value of <0.001. Since the p-value is less than the standard 0.05 significance level, the results indicate a statistically significant difference in the level of effectiveness between the two groups. These findings confirm that the traditional compound microscope performed significantly higher than the commercially available keychain microscope in visualizing peripheral blood smears in terms of contrast, sharpness, and structural visibility.

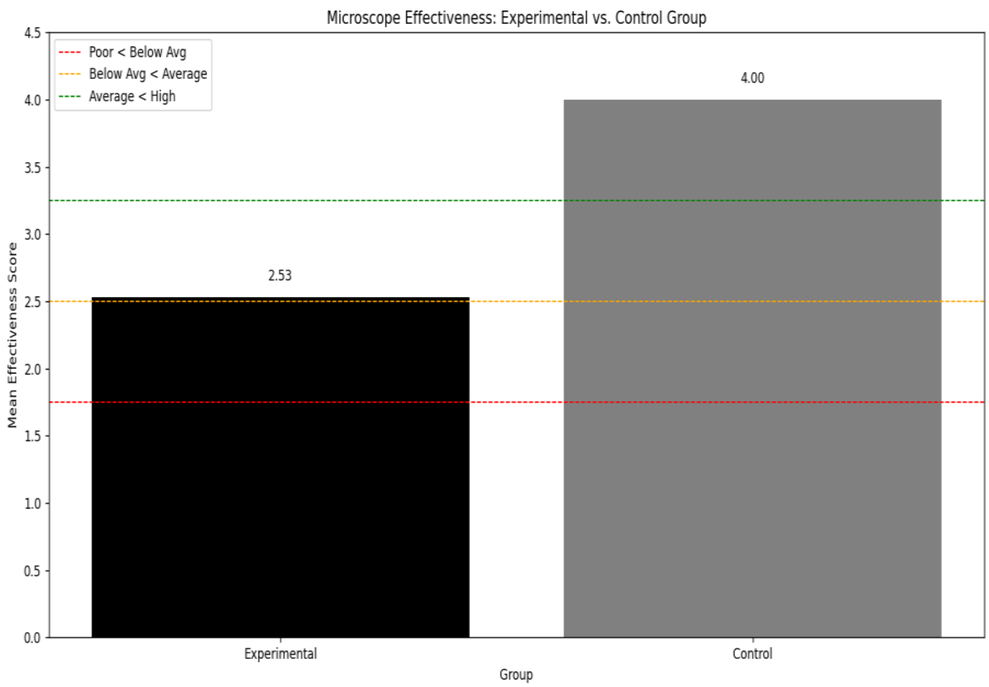

Figure 6: The Perceived Level of Effectiveness of Commercially Available Keychain Microscope (Weighted Mean of Contrast, Sharpness, Structural Visibility)

These findings are corroborated by existing literature. Schaefer et al. (2023) emphasized that while low-cost, portable microscopes have demonstrated significant value in educational outreach and introductory scientific demonstrations, they are generally limited in their capacity to produce high-resolution. Their optical limitations often result in reduced clarity, which impedes the accurate observation of fine cellular details. This observation is consistent with the study's findings, wherein the commercially-available keychain microscope was rated lower in terms of contrast, sharpness, and structural visibility compared to the traditional compound microscope. Similarly, Salido et al. (2022) highlighted that although smartphone-based microscopy devices provide a cost-effective means for promoting student engagement and experiential learning, their restricted optical performance limits their applicability in environments that require diagnostic precision. The effectiveness of the keychain microscope, as observed in this study, can be attributed to its inability to deliver consistent image sharpness and structural visibility. Thus, while the keychain microscope may serve as a practical tool for introductory instruction, it lacks the optical rigor necessary for more advanced educational laboratory applications.

The Significant Difference Between the Grade of Experimental Group and Control Group When Assessed According to Accuracy and Effectiveness

Parameter	T-Statistic	P-Value
Accuracy	–19.3411	<0.001 ($p < 0.05$)
Effectiveness	–27.6642	<0.001 ($p < 0.05$)

Table 6: T-Test Result of The Level of Accuracy and Effectiveness of The Commercially Available Keychain Microscope and Traditional Compound Microscope

Indicator: ($p < 0.05$) - there is a significant difference

The results of the accuracy assessment showed a significant difference between the experimental group (commercially available keychain microscope) and the control group (traditional compound microscope). The experimental group had a mean score of 2.74, categorized as "Moderately Clear and Accurate," while the control group scored 3.99, categorized as "Highly Clear and Accurate." This indicates that the keychain microscope, while functional, lacks the resolution and clarity provided by the traditional microscope. The t-test confirmed a statistically significant difference with a p-value less than 0.001 ($p < 0.05$), highlighting the higher accuracy of the traditional compound microscope.

Gouveia et al. (2024) stated that alternative microscopes such as Foldoscope is an innovative educational tool that can identify basic histological structures bridging the gap between theories and histological practice [32]. However, it is still incomparable to the traditional compound microscope due to its limitations in magnification, it lacks sharpness, and peripheral distortions may appear.

Brainmine (2022) highlighted the limitations of portable microscopes, particularly in resolution, making them less effective than traditional compound microscopes [33]. Their lightweight design often leads to instability during high-magnification viewing, which compromises image quality. Moreover, the limited features and camera resolution of smartphones reduce their overall effectiveness. While portable microscopes offer a low-cost educational alternative that enhances accessibility, their use in precision-demanding settings remains limited. As such, their role is best suited for introductory learning environments rather than professional or diagnostic applications.

Theme	Codes Included	Quotes (from RMTs and Pathologists)	Interpretation
Usability Challenges	Minor focusing difficulty, mild clarity issues under LPO	*"Focusing takes a bit of patience." "Image quality is okay but not as sharp as compound scopes." "Takes some time to adjust for a clearer view." "Lighting needs a little tweaking sometimes." "Slight glare when used directly under bright light."*	Respondents noted minor usability issues such as focusing adjustments and lighting conditions, but these are manageable with practice.
Portability Advantage	Compact, lightweight, mobile use	*"I could carry it anywhere without a problem." "Its size makes it ideal for outreach programs." "It's convenient for quick teaching demos." "I can easily store it in my lab coat pocket." "Great for mobile health education."*	The microscope's small size and mobility are praised, especially for its utility in fieldwork, mobile learning, or non-traditional educational settings.
Learning Constraints	Limited detail under LPO, basic visualization only	*"Helpful for general cell shapes but not fine features." "Some structures are visible, others are faint." "Decent for early learning levels." "Good for introductory lessons." "Not as detailed, but still useful for basic microscopy."*	The Makecroscope works well for foundational education but may not be suitable for advanced morphological instruction under LPO.
Engagement Booster	Fun, engaging, motivates learners	*"Students may find it exciting to use." "It increased curiosity in microscopy." "A good introductory tool for beginners." "Adds variety to classroom demos." "Innovative and interactive experience."*	The novelty and simplicity of the microscope foster student interest, making it an engaging learning supplement.
Cost-Effective ness	Affordable, resource-friendly	*"Very budget-friendly for schools." "A cost-efficient alternative to traditional scopes." "Affordable enough for students to own personally." "Perfect for institutions with limited funding." "Great value considering its portability and function."*	Respondents appreciated the affordability, making it suitable for personal and institutional educational use in resource-limited settings.

Table 7: Thematic Analysis of Identifying Trends Related to the Commercially Available Keychain Microscope

Table 7 shows the thematic analysis of the feedback from Registered Medical Technologists (RMTs) and Pathologists, revealing several perspectives on the educational use of the commercially available keychain microscope under Low Power Objective (LPO) conditions. While minor usability issues such as focusing and lighting adjustments were noted, these did not significantly hinder overall use. The microscope's portability was a major advantage, particularly for outreach programs and field-based education. Although it offers only basic visual clarity, it is suitable for activities that require wide-field observation. It proved effective in promoting hands-on learning and encouraging self-review, especially among students being introduced to microscopy. The commercially available keychain microscope was regarded as a practical and engaging tool for foundational exposure to microscopy—not as a replacement or supplementary device, but as a stand-alone aid for specific educational purposes.

Chou and Wang (2021) emphasized that while mobile microscopes are beneficial for educational purposes, they often require manual adjustments for focus and lighting [34]. These adjustments, although initially challenging, are typical of portable designs and become easier with continued use. This observation aligns with participant feedback in the current study, where users encountered similar issues but gradually adapted through hands-on practice and repeated use, which in turn enhanced their confidence in handling the device.

Similarly, McDermott et al. (2021) highlighted the role of low-cost microscopy tools in expanding access to science education, particularly in settings with limited resources. Their findings support the use of affordable, portable devices to bridge gaps in laboratory instruction and provide foundational exposure to microscopy. In line with this, participants in the study identified the keychain microscope's lightweight and compact design as a major advantage, especially in field-based learning and outreach activities where transporting traditional equipment would be difficult.

Reyes et al. (2024) further noted that while the initial use of such devices may present a learning curve, continuous improvements based on user experiences and feedback contribute to greater usability over time. This adaptability helps ensure that tools like the keychain microscope remain relevant and effective for hands-on learning, self-guided exploration, and early-stage scientific engagement, particularly in under-resourced or informal educational settings.

5. Discussion

This study was conducted in various diagnostic and health institutions within the First Congressional District of the Province of La Union and parts of Ilocos Sur. Specifically, data were gathered from the Municipal Health Units (MHUs) of Bacnotan, Balaoan, Bangar, City of San Fernando, Luna, San Gabriel, San Juan, Santol, and Santo Domingo, Ilocos Sur. Additional sites included the La Union Medical Diagnostic Center and Hospital, Inc. (LUMED), the Philippine National Police (PNP) – Vigan City, and the Metro Vigan Cooperative Hospital. Employing a mixed-methods research design, the study evaluated the accuracy, practicability, and effectiveness of commercially-available keychain microscope kits in peripheral blood smear (PBS) analysis. A total of 50 licensed medical professionals, consisting of 48 Registered [35,36].

Medical Technologists and 2 Pathologists, participated in the study through stratified sampling.
With respect to accuracy, the traditional compound microscope (control group) produced a higher mean score of 3.99, interpreted as "Highly Clear and Accurate." In comparison, the commercially-available keychain microscope (experimental group) produced a mean score of 2.74, interpreted as "Moderately Clear and Accurate." An independent sample t-test yielded a T-statistic of –19.3411 with a p-value less than 0.05, indicating a statistically significant difference between the two groups in terms of the accurate visualization of cellular morphology—specifically in the shape, color, and Wright staining of blood cells [37,38].

In terms of practicability, the commercially-available keychain microscope kits received favorable ratings. The participants rated ease of use with a mean of 3.26 and portability with a mean of 3.50, both interpreted as "Highly Practical." Cost-effectiveness was rated at 3.18, which fell under the interpretation of "Moderately Practical." These findings suggest that while the keychain microscope may lack precision, it provides notable advantages in terms of usability and accessibility [39].

Regarding effectiveness, the assessment focused on three key criteria: contrast, sharpness, and structural visibility of cell morphology. The results indicated that the commercially-available keychain microscope kits rated lower than the traditional compound microscope across all three parameters. The traditional compound microscope consistently provided more precise and distinguishable visualization of fine cellular details. In contrast, the commercially-available keychain microscope kits yielded reduced visual quality that required additional effort for interpretation [40].

These findings confirm that there is a significant difference between the experimental and control groups in both accuracy and effectiveness. The commercially-available keychain microscope kits are not recommended for use in core courses of the Medical Laboratory Science program or in clinical diagnostic procedures. Instead, they may be best suited for wide-view introductory exposure, basic familiarization with microscopy, or personal self-review purposes, especially in informal or resource-constrained educational contexts. Their use should be restricted to non-critical learning activities where high-resolution cellular detail is not required [41].

6. Conclusion

Based on the above findings, the researchers would like to articulate the following conclusions:

- The traditional compound microscope obtained a higher mean score of 3.99, interpreted as Highly Clear and Accurate. In contrast, the commercially available keychain microscope received a mean score of 2.74, interpreted as Moderately Clear and Accurate. The results of the independent t-test revealed a statistically significant difference between the two groups ($p < 0.05$), indicating that the keychain microscope lacks the necessary resolution and magnification to accurately assess cell morphology, particularly in color, shape, and stain (Wright stain).

- The keychain microscope received favorable ratings across three parameters: ease of use (mean = 3.26), portability (mean = 3.50), and cost-effectiveness (mean = 3.18). The first two parameters were interpreted as Highly Practical, while cost-effectiveness was interpreted as Moderately Practical. These results suggest that while the device is limited in precision, it is considered user-friendly, convenient, and accessible.
- The effectiveness of commercially available keychain microscope kits is limited in terms of resolution, specifically in contrast, sharpness, and structural visibility. When compared to the traditional compound microscope, the commercially available keychain microscope scored lower across all resolution indicators. This limitation implies that while general cell features may be observed, fine details required for morphological interpretation are not easily distinguishable. Thus, the keychain microscope's utility is best confined to activities where high-definition clarity is not essential, such as introductory demonstrations in cellular observation.
- There was a statistically significant difference between the grades of the control group (traditional compound microscope) and the experimental group (keychain microscope) in terms of both accuracy and effectiveness. The traditional compound microscope consistently outperformed the keychain microscope across all evaluation parameters. Due to its significantly lower performance, the keychain microscope is not suitable as a supplementary instructional tool in core Medical Laboratory Science (MLS) courses that require precise morphological assessment. However, its practicality, affordability, and ease of use suggest that it may still serve a limited role for individual self-review, general conceptual reinforcement, and early-stage microscopy exposure—particularly in non-clinical or informal educational settings where diagnostic precision is not required.

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