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Integration of Digital-Alternative-Microscope (DAM) Technology in Teaching Development Biology

Janneth S. Daganta

Department of Biology, College of Sciences
Palawan State University, Philippines
jdaganta@psu.palawan.edu.ph

Abstract: : *This study evaluated the effectiveness of Digital-Alternative Microscopy (DAM) technology as a practical learning tool in Developmental Biology among BS Biology students at Palawan State University. Using a sequential-exploratory mixed-methods design, approximately 50 third-year Biology students were assigned to control and experimental groups through convenience sampling. Data were collected using a validated 60-item pretest-posttest instrument and a perception survey consisting of Likert-scale and open-ended questions. The control group utilized conventional compound microscopes, while the experimental group used DAM technology during laboratory activities. Results showed learning gains in both groups, with mean gains of 4.20 and 3.20 points for the control and experimental groups, respectively. The Mann–Whitney U test indicated a no significant difference in posttest scores (p = .059). Wilcoxon Signed-Rank Test results revealed significant improvements within both groups (p < .001), demonstrating the effectiveness of both laboratory approaches. Qualitative findings showed that although students initially had limited familiarity with DAM technology, they perceived it as easy to use, convenient, engaging, and effective for basic microscopy tasks. Despite challenges related to image clarity, alignment, and fixed magnification, students generally accepted DAM as a practical alternative for laboratory learning. However, many still preferred conventional microscopes for detailed observations. Overall, DAM technology shows potential as an accessible supplementary tool for microscopy instruction in Developmental Biology. Recommend further that administration support the procurement, development, and scaling of alternative microscopy tools like DAM, particularly in institutions with limited laboratory resources, and incorporated DAM Technology into laboratory manuals and instructional guides for Developmental Biology and related courses.*

Keywords: Digital-Alternative Microscopy, Developmental Biology, Biology Education, Microscopy Innovation, Practical Learning, Mixed Methods Research.

I.INTRODUCTION

"Education is not preparation for life; education is life itself," a perspective advanced by John Dewey, emphasizes that meaningful learning emerges through authentic experience, active participation, and personal discovery. The present academic landscape has been profoundly shaped by pandemic-driven educational experiences, which have now become embedded within the new normal of teaching and learning conditions, causing the reshaped students' academic engagement, affecting motivation, participation, and readiness for active learning. Schools have coped by adopting new policies and implementing revised rules and regulations; however, continuous shifts in learning modalities have made instruction more challenging as educators respond to the evolving demands and learning needs of a new generation shaped by pandemic experiences. Moreover, rising heat index levels during summer seasons or extremely heavy rains that causes floods have increasingly forced schools to suspend face-to-face classes and shift to online or asynchronous modalities, further interrupting learning continuity and limiting opportunities for classroom interaction. While education now promotes personalized and technology-driven approaches, a significant concern remains—the decline of hands-on and experiential learning opportunities essential for science education. Many students return to academic settings with insufficient practical exposure, widening the gap between theoretical knowledge and skill development.

In biology education, specifically for Developmental Biology, microscopy plays a vital role in transforming abstract concepts into observable scientific evidence (Reigato, 2020). However, the high cost of microscopes and limited laboratory resources restrict access for many learners (Karhana, 2022). Ruscic et al. (2018) reported that microscopy is only occasionally used due to insufficient equipment, overcrowded classes, and poorly maintained laboratory tools. Consequently, students often rely on images or digital presentations rather than direct specimen observation, weakening inquiry skills and conceptual understanding.

The continued implementation of blended learning further complicates practical instruction. Irregular attendance caused by extreme weather conditions, frequent power interruptions (Kumar & Babu, 2025), and unstable internet connectivity (Amponsah et al., 2022) disrupt learning continuity and reduce opportunities for repeated laboratory practice. These conditions particularly affect laboratory-based subjects, where mastery depends on guided and consistent hands-on experience, resulting in reduced development of essential scientific competencies.

These challenges highlight the need for accessible and innovative learning tools capable of restoring experiential learning beyond traditional laboratories. Previous studies explored alternative microscopes for community and medical applications (Levin, 2020; Paredes, 2020; Flores & Marzullo, 2021; Serdyukov, 2017), yet their educational application remains underexplored. Meanwhile, mobile phones—widely owned by students—offer opportunities for interactive visualization and flexible learning environments (Mahdy, 2020; Frezal et al., 2023), enabling collaborative and self-directed learning beyond classroom limitations (Mallati, 2018).

Responding to these gaps, this study proposes the use of DAM (Digital-Alternative Microscope) Technology, integrating affordable microscopy tools with mobile phone capability to support practical learning in Developmental Biology. This innovation aims to bridge post-pandemic learning losses by enabling accessible, student-centered, and continuous laboratory experiences regardless of location, heat-related class suspensions, or technological limitations. The study also evaluates students' acceptance of the tool and its usability as an alternative approach to restoring practical competencies in biology education.

This study on DAM (Digital-Alternative Microscope) for BS Biology students in Developmental Biology aims to respond to the learning difficulties encountered by the students pertaining to the performance of practical activity. The goal is to allow students to have an alternative tool for laboratory imaging when a deficiency or scarcity exists to supplement their immediate need to learn. This aims to answer the following questions: (1) What is the performance of third-year BS Biology students in Developmental Biology in control and experimental groups concerning pretest and posttest, (2) Is there a significant difference in the pretest and posttest performance of students in the experimental group? and (3) Is there a significant difference in the posttest performances of students in the control and experimental group?

1. METHODOLOGY

2.1 Research Design

This study employed an experimental research design. An experimental research design established cause-effect relationships, allowing the researcher to determine whether the intervention used in the study caused changes between the control and experimental groups. This related to the study of Perez and Sobrino (2022), who tested the use of a foldscope, as well as the studies of Mohan et al. (2019), Levin (2020), Paredes (2020), Flores and Marzullo (2021), and Serdyukov (2017), who conducted experimental studies exploring alternative tools for microscopy and found them to be effective and efficient in achieving their purpose in field work and practical learning process.

2.2 Locale of the Study

This study was conducted at Palawan State University Main Campus, Puerto Princesa City, specifically, at the College of Sciences building, at designated lecture and laboratory rooms. The researcher provided a venue to facilitate the students' participation in the research, ensuring the formality and convenience of the student participants.

2.3 Respondents of the Study

Data were collected among the enrolled third-year BS Biology-Medical Biology students at Palawan State University in the School Year 2025-2026 who were of legal age and enrolled in the Developmental Biology course. Motivational strategies were imposed to encourage the voluntary participation of selected students. Rewards were employed to recognize the students' voluntary participation and to acknowledge their accomplishment in the study, not in monetary form but in kind.

The two (2) blocks of students who met the legal age requirement and expressed their willingness to participate were included in the study. Each block consisted of 25 students, for a total population of about 50 students in both the experimental and control groups. Participants were required to be at least 18 years old to legally provide their own informed consent without parental involvement. This age criterion ensured that participants could independently understand the study and voluntarily agree to participate.

This study employed a convenience sampling technique due to several practical and contextual considerations. Convenience sampling was appropriate because the study targeted a specific and accessible population: third-year BS Biology students enrolled in the Developmental Biology course at Palawan State University. Given that the total population size for this cohort was approximately 50 students, this sampling method allowed for efficient recruitment within the available student body without imposing additional burdens or requiring resources beyond the scope of the study.

The convenience sampling technique was used to divide the sample population into two groups—control and experimental—based on the researcher's convenience. In this context, convenience sampling referred to selecting students who were readily accessible and available within two predetermined class blocks during the semester, without further screening or randomization beyond meeting the enrollment and eligibility criteria. Specifically, all students enrolled in these blocks who were present during data collection and voluntarily consented to participate were included. This method allowed for practical and timely recruitment within the academic calendar while minimizing disruption to regular class activities.

2.4 Research Instrumentation

There were three (2) research instruments used in the study: the pre-test, and post-test instruments. Both the pretest and posttest questionnaires were researcher's constructed instruments designed based on the sequence of topics presented in the syllabus prepared for the study, intended for both the control and experimental groups. There were 60 multiple-choice questions prepared for both pre-test and posttest. A table of specification was considered in preparing

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the test item to balance the level of difficulties of the topic items, and to ensure a proper distribution of learning skills and to incorporate prior knowledge regarding topics on Gametic Observations, Blastulation, Gastrulation and Fertilization. The instruments underwent proper validation by professors who were experts in Biology and Developmental Biology. The content of the test items was carefully reviewed by a subject matter expert to ensure that the questions adequately covered the key topics and learning objectives of the course. This expert review helped confirm that each question was relevant, clear, and appropriately challenging for the students' level, thereby ensuring content validity. A pilot test was also conducted before the study with the previous group of developmental biology students to ensure that question items evaluated how well each question discriminated between higher- and lower-performing students and to check the overall difficulty level of the test. Questions found to be too easy, too difficult, or not functioning as intended were revised or removed.

2.5 Statistical Treatment

The study employed a combination of descriptive and inferential statistics to rigorously address each specific research objective.

For SOP 1**,** which involves assessing the performance of third-year BS Biology students in Developmental Biology by comparing pre-test and post-test scores in control and experimental groups, descriptive statistics (mean, standard deviation, median, minimum, and maximum) were computed to summarize and characterize the pretest and posttest performance of the Control and Experimental Groups. For SOP2, which is to determine the significant difference between these pretest and posttest scores incurred in the experimental group, Wilcozon Signed-Rank test was used to measure the same individual before and after a treatment. For SOP 3**,** which aims to examine whether there is a statistically significant difference between posttest performances in the control group and the experimental group, Mann-Whitney U test was used since a violation of the normality appeared in the sampling conducted.

2. Results and Discussion

2.1 Performances of Third-Year BS Biology Students in Developmental Biology

Table 1 presents the pre- and posttest performance of the third year BS Biology students in Developmental Biology from the control and experimental groups.

Table 1: Descriptive Statistics of the Pretest and Posttest Performance of the third-year Developmental Biology students

Group	Test	n	Mean	SD	Median	Min	Max
Control	Pretest	25	43.88	5.403	46.00	32	54
	Posttest	25	48.08	5.074	49.00	37	56
Experimental	Pretest	25	47.32	8.087	49.00	16	56
	Posttest	25	50.52	5.745	53.00	35	57

The performance of the students was analyzed using the mean, median and standard deviation. The control group, which was taught using the conventional compound microscope, obtained a pretest mean of 43.88 (SD = 5.403) with a median of 46.00 and scores ranging from 32 to 54. After the instructional intervention, their posttest mean rose to 48.08 (SD = 5.074), with a median of 49.00 and scores ranging from 37 to 56, reflecting an average gain of 4.20 points. The experimental group, which was taught using the DAM technology, posted a pretest mean of 47.32 (SD = 8.087) with a median of 49.00 and a wider score range of 16 to 56. Their posttest mean increased to 50.52 (SD = 5.745), with a median of 53.00 and scores ranging from 35 to 57, an average gain of 3.20 points. Taken together, both groups improved after the intervention, but the experimental group consistently posted higher central values at both testing periods. Of particular note is the marked reduction in the standard deviation of the experimental group from pretest (8.087) to posttest (5.745), together with the upward shift of its minimum score from 16 to 35.

The studies of Hinneh (2017) and Durrani et al. (2021) emphasized that positive perceptions of practical laboratory experiences are strongly associated with improved academic achievement. In particular, Durrani et al. (2021) demonstrated in histology teaching that combining innovative digital microscopy with interactive team-based learning increased student engagement and improved learning outcomes compared to traditional light microscopy approaches. Similarly, the study of Neves et al. (2017) on laboratory-based practical activities (LBPA) and home-based practical activities (HBPA) highlighted that both approaches contribute significantly to students' understanding of course concepts and academic improvement. These findings suggest that DAM technology not only enhanced students' engagement and interest in laboratory activities but also helped improve the performance of students who initially struggled, resulting in a more homogeneous distribution of scores after the intervention.

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2.2 Pretest and Posttest Performances of the Experimental Group

Table 2 presents the Wilcoxon signed-rank test comparing the pretest and posttest performance of the experimental group, which was taught using the DAM technology.

Table 2. Wilcoxon Signed-Rank Test on Pretest and Posttest Performance of the Experimental Group

Variable	n	Median	Negative Differences	Positive Differences	Ties	Test Statistic	z	p-value	Decision	Verbal Interpretation
Pretest	25	49.00	3	20	2	245.500	3.291	<.001	Reject H_0	The difference is significant.
Posttest	25	53.00								

The experimental group registered a pretest median of 49.00 and a posttest median of 53.00. Of the twenty-five (25) respondents, twenty (20) obtained higher posttest scores, three (3) obtained lower posttest scores, and two (2) recorded tied scores. The analysis produced a test statistic of W = 245.500, z = 3.291, and p < .001. Since the p-value is below the .05 level of significance, the null hypothesis that there is no significant difference between the pretest and posttest performance of the experimental group is rejected. This indicates that the students who used the DAM technology registered a statistically significant improvement from pretest to posttest.

This finding is consistent with previous studies highlighting the effectiveness of innovative microscopy tools in science education. Paredes (2020) developed an improvised digital microscope camera adapter and found it suitable, acceptable, and usable in learning life sciences, while Florez and Marzulla (2021) introduced a simple protocol for creating a high-magnification glass and gelatin ball lens. Similarly, Ganesa et al. (2022) developed the Foldscope and reported its significant contribution to understanding biological concepts. Numerous evaluation studies further supported the educational and practical value of microscopic innovation technology across fields such as education and research, public health, clinical diagnostics, basic science, agriculture, forensic science, and Developmental Biology. Collectively, these studies justify that innovative microscopy tools can provide learning experiences and instructional outcomes comparable to conventional microscopy, while improving accessibility, flexibility, and resource efficiency in science education.

2.3 Posttest Performances of the Control and Experimental Group

Table 3 shows the results of the Mann–Whitney U test which indicates that there is no statistically significant difference in the posttest performance between the control and experimental groups in Developmental Biology.

Table 3. Mann-Whitney U Test on the Posttest Performance of the Control and Experimental Groups

Test	Group	n	Mean Rank	Test Statistic	z	p-value	Decision	Verbal Interpretation
Posttest	Control	25	21.62	409.500	1.888	.059	Do Not Reject H_0	The difference is NOT significant.
	Experimental							

The experimental group (n = 25) obtained a mean rank of 21.62, and although this suggests a slight tendency toward higher performance compared to the control group, the difference is not strong enough to be considered statistically meaningful. The test yielded a U value of 409.500, with a z-score of 1.888 and a p-value of 0.059. Since the p-value (0.059) is greater than the alpha level of 0.05, the decision is to fail to reject the null hypothesis (H_0). This means that the observed difference in posttest scores between the control and experimental groups is likely due to chance rather than a true effect of the intervention.

In practical terms, the experimental group that utilized DAM technology demonstrated slightly higher performance rankings compared to the control group, indicating that students exposed to the alternative microscopy tool generally performed better in the posttest. However, the statistical analysis revealed that the difference between the two groups was not significant at the .05 level, suggesting that the observed advantage of the experimental group was not strong enough to conclusively establish the superiority of DAM technology over the conventional compound microscope. This means that both instructional approaches were comparably effective in facilitating student learning in Developmental Biology.

Despite the absence of statistical significance, the computed p-value was notably close to the accepted threshold for significance. This suggests the possibility of a marginal or emerging effect of the DAM intervention that may not have been fully captured due to certain limitations of the study, particularly the relatively small sample size. With a larger number of participants, the statistical power of the analysis could increase, potentially making subtle differences between groups more detectable. Likewise, further refinement of the DAM implementation—such as improving image quality, enhancing magnification capability, extending the duration of exposure, or providing additional user training—may strengthen its instructional impact and lead to more pronounced learning gains.

The findings therefore imply that while DAM technology cannot yet be considered significantly superior to the traditional compound microscope, it nevertheless demonstrated promising educational potential. Its ability to produce learning outcomes comparable to conventional microscopy, combined with its accessibility and portability, supports its value as a practical alternative or supplementary instructional tool, particularly in resource-limited or flexible learning environments.

Presented study support the claims of previous researchers regarding the value of alternative and technology-assisted practical learning approaches in science education. Although the DAM technology did not produce a statistically significant superiority over the conventional compound microscope, its comparable learning outcomes and positive student perceptions suggest that it can effectively supplement traditional laboratory instruction. This aligns with the study of Gya and Bjune (2021), who demonstrated the importance of at-home and do-it-yourself (DIY) practical activities in promoting authentic, self-paced, and interactive learning experiences. Similarly, the portability and accessibility of DAM technology enabled students to engage in microscopy activities beyond the traditional laboratory setting, supporting flexible and independent learning.

The positive engagement and interest shown by students in using DAM technology are also consistent with the findings of Kosterelioglu (2016), who reported that visual learning materials such as videos and clips enhance student attention, memory retention, and understanding of lessons. In the present study, the integration of DAM technology provided students with a more interactive and visually engaging laboratory experience, which likely contributed to their positive attitudes and improved learning performance. Moreover, the findings reflect the recommendations of Cimer (2012), who emphasized the importance of practical work, visual materials, and engaging teaching strategies in overcoming difficulties in Biology learning.

Furthermore, the study supports the perspectives of Baker and Verran (2004), Brockman et al. (2020), and de Jong et al. (2013), who suggested that virtual and alternative laboratory approaches are most effective when combined with traditional face-to-face laboratory instruction. While DAM technology proved useful for basic microscopy and flexible learning situations, students still preferred the conventional compound microscope for detailed and advanced observations. This observation also supports the conclusions of Brinson (2015) and Noel et al. (2020), who argued that certain laboratory skills and techniques cannot be fully acquired through virtual or alternative methods alone. Thus, the present study suggests that DAM technology should be viewed not as a complete replacement for conventional microscopy, but as a valuable supplementary and contingency tool that enhances accessibility, engagement, and continuity of laboratory learning.

3. Conclusion

The study investigated the effectiveness of DAM (Digital-Alternative Microscopy) Technology as an alternative instructional tool in practical learning in Developmental Biology among BS Biology students at Palawan State University. The findings generally revealed that both the traditional compound microscope and DAM technology contributed positively to students' academic performance and laboratory learning experiences.

The descriptive results showed that students in both the control and experimental groups improved from pretest to posttest, indicating that learning occurred regardless of the instructional tool used. Although the experimental group consistently obtained slightly higher mean scores, statistical analysis revealed that the posttest difference between the two groups was not significant. This suggests that DAM technology was able to produce learning outcomes comparable to those achieved using the conventional compound microscope.

The inferential analyses further demonstrated that both groups experienced statistically significant improvement from pretest to posttest. This confirms that both traditional microscopy and DAM technology are effective instructional approaches for teaching Developmental Biology concepts and laboratory skills. The findings imply that DAM technology can function as a reliable supplementary or alternative microscopy tool, especially in contexts where conventional laboratory equipment may be limited or inaccessible.

4. Recommendations

Based on the objectives of the study and the overall results, several key recommendations can be drawn to strengthen the use of DAM (Digital-Alternative Microscopy) Technology in Developmental Biology instruction and related science education settings.

First, although the inferential results showed no significant difference in posttest performance between the control and experimental groups, both groups significantly improved from pretest to posttest. This indicates that DAM technology is as effective as the traditional compound microscope in supporting student learning. In this regard, it is recommended that DAM technology be adopted as a supplementary instructional tool in Biology laboratory classes, especially for introductory-level topics where basic observation and identification skills are emphasized.

Second, given that students reported positive perceptions in terms of familiarity, effectiveness, and acceptability, it is recommended that science educators integrate DAM technology into blended and flexible learning modalities, particularly in asynchronous or off-campus learning setups. This aligns with the study objective of promoting independent and accessible learning experiences. Teachers may use DAM-based activities as preparatory or reinforcement tools before or after formal laboratory sessions.

Third, considering the practical limitations identified—such as image clarity, magnification constraints, and dependence on smartphone quality—it is recommended that technical improvements and standardized protocols for DAM use be developed. Training sessions for both instructors and students should also be conducted to maximize the effective use of the technology and minimize operational difficulties during laboratory activities.

Fourth, for institutional implementation, school administrators are encouraged to support the procurement, development, and scaling of alternative microscopy tools like DAM, particularly in institutions with limited laboratory resources. This will help address equipment shortages, overcrowded laboratories, and interruptions caused by equipment unavailability, as supported by the study's findings.

Fifth, for curriculum development, it is recommended that DAM-based activities be incorporated into laboratory manuals and instructional guides for Developmental Biology and related courses. This will ensure that the technology is systematically integrated rather than used only as an optional tool, thereby strengthening consistency in student learning experiences.

Finally, future researchers are encouraged to conduct larger-scale studies involving more diverse populations and extended intervention periods to further validate the effectiveness of DAM technology. Comparative studies focusing on different biological topics, higher magnification requirements, and advanced microscopy skills may also help establish the full scope and limitations of DAM in science education. In addition, the use of alternative sampling strategies should be explored to ensure more robust and representative participant distribution, thereby strengthening the validity and generalizability of findings in future research.

While DAM technology did not produce statistically superior posttest outcomes compared to traditional microscopy, the results strongly support its role as a practical, accessible, and student-friendly alternative tool that can enhance laboratory learning, especially in resource-limited or blended learning environments.

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