



The experiential learning model based on household waste for the understanding of plant cell concepts



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ABSTRACT

The persistent weakness in students' mastery of plant cell concepts indicates a structural problem in conventional science instruction, particularly the lack of direct conceptual construction experiences. The purpose of this study is to determine whether the experiential learning model based on household waste affects students' conceptual understanding of plant cell material. This study examines the impact of experiential learning using improvised microscopes assembled from household waste materials on eighth-grade students at MTs Negeri 3 Kota Palu. The research employed a quasi-experimental method with a non-equivalent control group design. Two classes were purposively selected: class VIII F as the experimental group and class VIII H as the control group. Data were collected through pre-test and post-test essay instruments aligned with conceptual understanding indicators. Statistical analysis showed a significant effect, indicated by an independent sample t-test significance value of 0.000, below the 0.05 level. The experimental group obtained higher mean post-test scores than the control group, demonstrating that experiential learning supported by simple waste-based microscopes effectively improves students' conceptual understanding of plant cells in science learning.

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INTRODUCTION

The emergence of the Industrial Revolution 4.0, frequently referred to as the technological or digital revolution, has profoundly reshaped human patterns of living, working, and social interaction, with education standing as one of the most affected domains (Wahyudi & Novita, 2021). Historically, industrial development has unfolded through four major phases, each characterized by distinct technological transformations and shifts in production systems. Across

these stages, human labor has increasingly been substituted or augmented by mechanization and automated technologies (Riska Intan Pramitaning Tyas & Muhammad Yasin, 2024). In the current digital era, the rapid evolution of information and communication technology demands educational innovation capable of producing learning processes that are not only efficient but also adaptive and relevant (Heryani et al., 2022). Consequently, education is positioned as a strategic foundation for cultivating individuals who are intellectually capable, competitive, creative, and equipped to engage within a globalized society shaped by the dynamics of Revolution 4.0 (Sulistyarini et al., 2022).

As mandated by Law Number 20 of 2003 on the National Education System, education constitutes a deliberate and structured endeavor designed to facilitate learning environments that actively enable learners to develop their inherent potential. National education aspires to shape individuals who possess faith, ethical integrity, competence, creativity, independence, and civic responsibility (Antikha Ayu et al., 2019). Alongside this normative framework, global technological advancement continues to accelerate and exerts a substantial influence on educational practices and orientations (Ariska & Alawiyah, 2019). Education, therefore, functions as a systematic process through which learners acquire competencies beneficial to themselves, society, and the nation, provided that learning activities are implemented in a planned and coherent manner (Safitri, 2023). The recurring issue of suboptimal learning outcomes reflects the urgency of reforming instructional quality, particularly by transforming monotonous and teacher-centered practices into learning experiences that are engaging, meaningful, and participatory through the adoption of active learning models (Muafiah Nur, 2023).

Natural Science represents a core subject introduced at the basic education level, aiming to equip learners with scientific facts, concepts, and principles related to natural phenomena while fostering the ability to apply scientific knowledge in everyday contexts. Beyond factual acquisition, science education is expected to cultivate scientific attitudes and reasoning skills among students (Salim Nahdi et al., 2018). Central to this objective is conceptual understanding, which implies that learners not only recognize scientific terms but can articulate concepts independently and apply them in real-life situations. Effective science learning emphasizes conceptual depth and contextual relevance so that knowledge becomes meaningful rather than merely memorized. Such meaningful learning is attainable when educators design instructional processes that prioritize student engagement and active participation, rather than relying solely on verbal explanation or passive listening (Harefa et al., 2022). Instructional media holds a strategic role in educational settings as it supports, accelerates, and clarifies the delivery of learning content, thereby facilitating students' comprehension. The integration of suitable learning media contributes to increased instructional effectiveness by creating learning environments that are interactive, engaging, and conceptually meaningful (Azhura et al., 2024). However, limited access to laboratory equipment, such as light microscopes, remains a challenge for many schools. In response, simple microscopes constructed from reused materials have been developed as alternative learning tools, enabling both teachers and students to engage in observational activities without reliance on costly equipment (Ma'arif Ikhsannudin et al., 2022). The utilization of household waste materials—such as discarded cardboard and plastic bottles—as educational media demonstrates the potential of low-cost innovation to enhance conceptual understanding, particularly in science topics related to cell structure and function (Kharismawati & Desstyia, 2021). Accordingly, this study integrates experiential learning as an experience-based instructional model supported by such media.

Explaining the central role of conceptual understanding in biology education, particularly plant cells as the foundation for understanding photosynthesis, osmosis, and cellular respiration. Accompanied by the fact that the concept of cells is one of the more complex topics. This is thought to be due to the abstract nature of the material in the sub-concepts of plant and animal cell



organelles as well as the sub-concept of transport mechanisms. According to them, the low student learning outcomes are caused by differences in students' absorption capacity and retention ability (Agustina et al., 2020). Student learning difficulties are influenced by several factors, including a lack of student understanding and focus on the material, teaching strategies that are less engaging thus reducing learning motivation, as well as a lack of learning media that actively involve students in the learning process, and limited learning resources available as additional references. (Muliati 2025 et al., n.d.)

Experiential Learning is conceptualized as a comprehensive instructional model that frames learning as a continuous process of experience, reflection, and personal development. The emphasis on “experience” distinguishes this approach from cognitive or behaviorist theories that primarily focus on mental processing or observable behavior alone (Sajiatmojo et al., 2022). Through direct engagement with learning activities, students are encouraged to construct meaning from firsthand experiences. This aligns with the perspective articulated by Suryani, Ely Rudyatmi, and Tyas Agung Pribadi, who argue that experiential learning enhances learner motivation, fosters an enjoyable learning atmosphere, and promotes active involvement, thereby creating a more open and participatory classroom environment (Maisyaroh & Sabri, 2018).

Preliminary observations conducted at MTs Negeri 3 Palu identified several instructional challenges, including low student interest and limited attention during learning activities. These issues were largely attributed to the persistent use of conventional teaching methods that lacked variation, combined with the absence of adequate learning media and laboratory facilities. As a result, instructional content was not optimally absorbed, and students experienced difficulty in understanding scientific material. Supporting this observation, Wijaya et al. (2025) emphasize that insufficient use of learning media can diminish students' motivation and negatively affect learning outcomes. Learning environments that lack appropriate media tend to become monotonous and ineffective, leading to decreased engagement and achievement across cognitive, affective, and psychomotor domains. Similar findings reported by (Pendidikan et al., n.d.) indicate that many students fail to reach the Minimum Completeness Criteria (KKM) in science subjects due to limited instructional variation and inadequate media utilization.

The novelty of this study lies in the integration of experiential learning with a simple microscope constructed from household waste materials to facilitate direct observation of plant cells. Unlike previous studies that applied experiential learning using conventional or laboratory-based media, this research combines experience-based pedagogy with low-cost, environmentally sustainable instructional tools. This approach not only enhances conceptual understanding through concrete learning experiences but also introduces ecological awareness and practical innovation in science instruction, particularly in schools with limited laboratory facilities. The purpose of this study is to determine whether the experiential learning model based on household waste has an effect on students' conceptual understanding of plant cell material.

RESEARCH METHODS

Research Design

This research employs a quantitative methodology with a quasi-experimental design, specifically adopting a nonequivalent control group structure that distinguishes between experimental and control groups (Hastjarjo, 2019). The experimental group engaged in science learning supported by simple microscope media, whereas the control group received conventional instruction without such media.

Population and Samples

The study population consisted of 155 eighth-grade students enrolled at MTsN 3 Kota Palu. From this population, two classes, VIII F as the experimental group and VIII H as the



control group, were selected through purposive sampling. This sampling strategy was chosen based on considerations of students' relatively equivalent academic abilities and recommendations from the science teacher, ensuring that the selected classes possessed comparable characteristics and aligned with the objectives of the research. The study population comprised all eighth-grade students at MTs Negeri 3 Kota Palu. Sample selection was conducted using purposive sampling based on recommendations from the science subject teacher, resulting in class VIII F (15 students) as the experimental group and class VIII H (15 students) as the control group.

Instruments

Research instruments included a conceptual understanding assessment consisting of seven validated essay questions aligned with seven indicators of conceptual comprehension: (a) restating concepts, (b) classifying objects, (c) providing examples and non-examples, (d) representing concepts in mathematical forms, (e) selecting and applying procedures, (f) implementing concepts or algorithms in problem-solving, and (g) formulating necessary and sufficient conditions of a concept (Sari & Yuniati, 2018). Additional instruments comprised observation sheets to assess the implementation of learning activities using simple microscopes, as well as documentation in the form of photographs, student worksheets (LKPD), teaching modules, and supplementary materials.

Procedures

The research workflow was initiated through an extensive preparatory phase that did not immediately involve classroom intervention. This early stage consisted of conducting a situational diagnosis of learning conditions, formulating instructional devices, and designing an assessment instrument aimed at measuring students' conceptual comprehension. The conceptual understanding test was subjected to a validation process involving expert reviewers and underwent multiple revisions until it was formally declared appropriate for implementation. Following this preparatory phase, empirical activities commenced with the administration of a pretest to capture students' baseline conceptual understanding before instructional treatment. The learning intervention was then implemented in accordance with the designated instructional scenario. Upon completion of the entire learning sequence, a posttest was administered to assess changes in students' conceptual understanding. The resulting pretest and posttest data were subsequently processed through prerequisite statistical analyses, including normality and homogeneity testing, before further inferential analysis was conducted.

Data Analysis

Data analysis followed multiple analytical steps. First, validity and reliability testing were performed through expert judgment to evaluate instrument feasibility, clarity, and alignment with conceptual indicators (Rindiasari, Hidayat, Yuliani et al., 2021). Second, prerequisite analyses included a normality test using the Shapiro–Wilk method with a significance level of $\alpha = 0.05$ (Zulkifli et al., 2025) and a homogeneity test using Levene's Test at the same significance level. Finally, hypothesis testing was conducted using an Independent Sample t-Test with $\alpha = 0.05$ to determine the effect of the treatment (Wiliawanto et al., 2019).

RESULTS

The instructional approach applied in this study was experiential learning, supported by a simple microscope constructed from household waste materials as the primary learning medium. The instructional content centered on plant cell topics, which were explored through direct observational activities involving real plant cell specimens. Learning implementation followed a structured experiential learning cycle, beginning with concrete experience in the form of direct observation using the simple microscope. This was followed by reflective activities in which



students analyzed and discussed their observation results. Subsequently, abstract conceptualization was facilitated through group discussions and presentations aimed at formulating plant cell concepts. The cycle concluded with active experimentation, wherein students related their observational findings to given problems or guiding questions. The learning process was organized into sequential stages, starting with introductory activities, progressing to core activities encompassing observation, discussion, and presentation, and ending with closing activities (Ulfah et al., n.d.).

Students' conceptual understanding was assessed through the administration of pretests and posttests in both the experimental and control classes. Quantitative results obtained from these assessments are summarized and displayed in the corresponding table

Table I. Descriptive Statistics of Pretest and Posttest Results

No.	Groups	N	Minimum	Maximum	Mean	Std. Deviation
1	Pre-Test Experiment	15	16	23	19,47	2,066
2	Post-Test Experiment	15	48	79	66,67	8,491
3	Pre-Test Control	15	10	20	15,53	3,441
4	Post-Test Control	15	41	65	53,53	7,586
5	Valid N (listwise)	15				

As illustrated in Table I, the mean pretest scores of the experimental class (19.47) and the control class (15.53) show no substantial discrepancy, suggesting that both groups entered the learning process with relatively comparable initial conceptual abilities. In contrast, post-intervention results reveal a noticeable divergence, where the experimental class achieved a higher average posttest score (66.67) compared to the control class (53.53). This difference amounts to 13.14 points, indicating a meaningful variation in learning outcomes following the treatment.

The disparity observed in posttest mean scores between the experimental and control groups signifies that the experiential learning model supported by a waste-based simple microscope contributes positively to the enhancement of students' conceptual understanding. This outcome can be attributed to the nature of experiential learning, which provides learners with direct engagement through plant cell observation activities

Such tangible experiences allow abstract biological concepts to be perceived in a concrete manner, reducing cognitive barriers to understanding. Furthermore, students' active participation during observation, discussion, and reflection phases facilitates independent concept construction and deeper cognitive processing. Learning that emphasizes experience and student-centered activity ultimately leads to improved conceptual mastery, as reflected in the superior posttest outcomes. These findings are consistent with the study conducted by Wardiana Rahayu et al. (2024), which reported comparable initial conceptual understanding levels between experimental and control groups, both categorized as low. After instructional treatment, posttest data were analyzed using N-Gain normalization and the Mann–Whitney test due to non-normal data distribution. The results demonstrated that experiential learning was more effective than conventional instruction in improving conceptual understanding. Similarly, Laraswati (n.d.) reported that the experimental class achieved an average gain index of 0.343 (moderate category), while the control class obtained 0.036 (low category), with a gain significance value of 0.000, indicating superior conceptual improvement in the experimental group.

The normality test was conducted using the Kolmogorov–Smirnov and Shapiro–Wilk tests to determine whether the pretest and posttest scores in both the experimental and control classes were normally distributed.

Table 2. Normality Test Results

No.	Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
1	Pre-test Control	.163	15	.200*	.922	15	.209
2	Post-test Control	.189	15	.157	.934	15	.316
3	Pre-test Experiment	.135	15	.200*	.955	15	.604
4	Post-test Experiment	.158	15	.200*	.949	15	.510

As shown in Table 2, all significance values obtained from both tests were greater than 0.05. Specifically, the Shapiro–Wilk significance values for the control class were 0.209 (pretest) and 0.316 (posttest), while for the experimental class they were 0.604 (pretest) and 0.510 (posttest). Similarly, the Kolmogorov–Smirnov test produced significance values of 0.200 and 0.157 for the control class, and 0.200 and 0.200 for the experimental class.

Since all significance values exceeded the threshold of 0.05, it can be concluded that the pretest and post-test data in both groups were normally distributed. Therefore, the assumption of normality was fulfilled, allowing further parametric statistical analysis to be conducted. The outcomes of the normality analysis indicate that all datasets yielded significance values greater than 0.05. This finding confirms that both pretest and posttest scores from the experimental and control classes are normally distributed. The homogeneity test was conducted using the Levene Test to determine whether the variance between groups is homogeneous. The test results show that the obtained significance value is compared to the predetermined significance level ($\alpha = 0.05$). If the significance value is greater than 0.05, it can be concluded that the data have homogeneous variance, so the assumption of homogeneity is fulfilled.

Table 3. Homogeneity Test Results

No.		Levene Statistic	df1	df2	Sig.
1	Results — Based on Mean	.039	1	28	.846
2	Based on Median	.012	1	28	.913
3	Based on Median and with adjusted df	.012	1	26.643	.913
4	Based on the trimmed mean	.032	1	28	.859

The homogeneity of variance test was conducted using Levene's Test to determine whether the variance of scores between the experimental and control groups was equal. As presented in Table 3, the significance value based on the mean was 0.846, while the values based on the median and adjusted median were 0.913, and the trimmed mean was 0.859. Since all significance values are greater than 0.05, it can be concluded that there is no significant difference in variance between the two groups, indicating that the assumption of homogeneity of variance is satisfied. After satisfying all prerequisite statistical assumptions, hypothesis testing was carried out using the Independent Sample t-Test, with the results documented accordingly.

Table 4. Independent Samples Test

No		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
1	Hasil — Equal variances assumed	.039	.846	-4.467	28	.000	-13.133	2.940	-19.156	-7.111
2	Equal variances not assumed			-4.467	27.652	.000	-13.133	2.940	-19.159	-7.107



Based on Table 4, the results of the Independent Sample t-Test indicate that the significance value in Levene's Test (Sig.) was 0.846 (> 0.05). This indicates that the variance of both groups is homogeneous, so the analysis was continued using the Equal variances assumed row. In the t-test for Equality of Means, the significance value (Sig. 2-tailed) obtained was 0.000 (< 0.05). Therefore, there is a significant difference between the average learning outcomes/conceptual understanding of students in the experimental class and the control class. The calculated t-value of -4.467 with degrees of freedom ($df = 28$) indicates that the difference is statistically significant. The Mean Difference of -13.133 indicates that there is a score gap of 13.133 points between the two groups. The 95% confidence interval ranges from -19.156 to -7.111, which does not pass through zero, further confirming the existence of a significant difference. Therefore, it can be concluded that the use of the experiential learning model based on household waste has a significant effect on students' conceptual understanding of plant cell material compared to conventional learning.

DISCUSSION

These findings are aligned with prior research by Razaq Wardhana and Rahmad (2024a), which reported superior conceptual understanding outcomes in classes applying experiential learning across all achievement indicators. Additional support is provided by Salsa Bila et al. (2024), who found that experiential learning promotes active participation, facilitates understanding through direct experience, and strengthens the linkage between theory and practice. Moreover, experiential learning has been shown to enhance learning motivation, science process skills, and conceptual comprehension. The distinctive contribution of the present study lies in the integration of a simple microscope derived from household waste, which introduces contextual and authentic learning experiences that further reinforce plant cell concept understanding.

The present findings are consistent with the research of Apriovilita Hariri and Yayuk (n.d.), which demonstrated that experiential learning implemented through four sequential stages—concrete experience, reflective observation, abstract conceptualization, and active experimentation—successfully improved students' self-confidence and science concept comprehension. This improvement was reflected in increased class average scores from 72.2 in cycle I to 79.6 in cycle II, as well as enhanced learning mastery from 47.4% to 78.9%. Likewise, Mufida and Qosyim (n.d.) reported N-Gain values of 0.75 (high category) for the experimental class and 0.62 (moderate category) for the control class, indicating superior conceptual improvement among students exposed to experiential learning. These results were reinforced by a student response rate of 96.7%, categorized as very good. In parallel, Razaq Wardhana and Rahmad (2024b) also confirmed the effectiveness of experiential learning in enhancing conceptual understanding among eleventh-grade students in light and optics material using a quasi-experimental posttest-only control design.

The experiential learning model offers multiple pedagogical advantages, including the enhancement of self-confidence, communication competence, planning ability, and problem-solving skills, as well as the cultivation of responsibility, trust, cooperation, and compromise within collaborative learning contexts (Hakima & Hidayati, 2020). Ihwan Zulkarnain (2020, n.d.) further emphasizes that experiential learning positively influences students' mathematical conceptual understanding by increasing enthusiasm, encouraging experiential reflection, promoting active engagement in group discussions, and fostering creative problem-solving. Supporting this perspective, Mertayasa et al. (2024) reported that a synthesis of four empirical studies indicates that experience-based learning models consistently produce significant improvements in students' critical thinking skills. Compared to conventional instruction, experiential learning more effectively

enhances analytical reasoning, evaluative judgment, and evidence-based conclusion formulation, while simultaneously increasing student engagement and motivation.

CONCLUSION

In summary, the implementation of the experiential learning model supported by a simple microscope derived from household waste exerts a statistically significant influence on students' conceptual understanding of plant cell material among eighth-grade students at MTs Negeri 3 Kota Palu, as indicated by a significance value of $0.000 < 0.05$. The experimental class achieved a higher mean posttest score (66.67) than the control class (53.53), with a difference of 13.14 points. These results affirm that experiential learning integrated with low-cost, waste-based instructional media constitutes an effective alternative strategy for enhancing conceptual understanding in science learning, particularly in the context of plant cell topics.

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