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Visualization of the Osmotic Pressure Concept Through Plasmolysis Observation in Rhoeo discolor: A Physiological Study for Science Education

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Short Report

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Abstract

Plasmolysis is a physiological phenomenon that occurs in certain plant tissues, particularly the epidermis, driven by the process of osmosis. However, osmotic pressure often remains an abstract concept in science education, necessitating a concrete visualization. This study aims to explain the morphological changes in the epidermal cells of Rhoeo discolor before and after plasmolysis, and to analyze the causative factors of this phenomenon. A qualitative descriptive method was employed in this experiment. The epidermal tissues were observed under a microscope at 4x and 10x magnifications. Two treatments were applied: water as a neutral medium and a NaCl solution as a hypertonic medium. The results showed that when exposed to water, the epidermal cells appeared tightly packed with a deep purple color, indicating that no plasmolysis occurred. Conversely, exposure to the NaCl solution caused the cells to become loosely arranged and the deep purple color to fade to pale, confirming the occurrence of plasmolysis. This condition is caused by the hypertonic nature of the salt solution, which draws water out of the cells, causing them to shrink. It can be concluded that the distinct color and structural changes in Rhoeo discolor make it an excellent and highly accessible biological model for visualizing osmotic pressure, thereby enhancing conceptual understanding in science education.

1. Introduction

Students struggle to visualize and understand phenomena that are not directly observable, such as atoms, molecules, and quantum effects (Indriyanti & Barke, 2017; Dumin et al., 2022). This leads to reliance on common sense or classical reasoning, which is often inadequate for abstract scientific ideas (Seangdeang & Yasri, 2029; Haeusler & Donovan, 2020; Firdaus, 2025). The specific problem lies in the traditional, transmission-based pedagogical approaches that fail to visually engage students in complex mechanisms (Hennessy et al., 2007; Lashari et al., 2026). This global education challenge has significant broader implications (Firdaus & Nurohman, 2025), as a lack of foundational understanding in cellular physiology hampers students' progression into advanced STEM (Science, Technology, Engineering, and Mathematics) fields (Rinneheimo & Mierluş-Mazilu, 2024). Transitioning to a national context, science education in countries like Indonesia frequently grapples with limited laboratory resources (Firdaus et al., 2024), making it difficult to demonstrate abstract physiological phenomena. Therefore, finding accessible, low-cost, and visually clear biological models is imperative to bridge the gap between theoretical science and practical understanding.

The primary issue addressed in this study is the cognitive difficulty students face when learning about osmotic pressure and cell membrane dynamics, which often results in rote memorization rather than meaningful comprehension (Muller et al., 2021; Rice et al., 2022; Walton, 2023). Understanding osmosis is critical because water and minerals in the cytoplasm play a vital role in cell metabolism, dictating the diffusion and osmosis flow in and out of the cell (Nursita et al., 2020). However, the real-world implication of failing to grasp this concept is a generation of students who cannot connect microscopic cellular behavior to macroscopic environmental adaptations, such as how plants survive drought or salinit. By connecting this global educational challenge to a specific physiological focus, this study

highlights the necessity of transforming the invisible mechanisms of water transport into observable events through plant tissue practicums.

Existing literature presents several key perspectives regarding plant tissue physiology and cellular dynamics. First, from an anatomical perspective, plant organs consist of various cells with distinct structures and functions, forming tissues where adjacent cell membranes are connected via plasmodesmata, allowing water and small solutes to move freely (Nugroho, 2021). Second, regarding the physiological mechanism, plasmolysis is defined as the detachment of the cytoplasmic membrane from the cell wall due to cellular shrinkage when placed in a hypertonic solution (Maulida et al., 2024). This contrasts with plasmoptysis, which occurs in hypotonic solutions causing cells to swell and burst (Maulida et al., 2024). Third, from a cellular viability standpoint, plasmolysis is widely recognized as a useful tool for testing plant cell survival, as it only occurs in living cells with intact semipermeable membranes; dead cells cannot undergo plasmolysis (Harant & Lang, 2021).

While scholars like Harant & Lang (2021) explore the advanced 3D structural membrane-wall contacts in moss, and Shinde et al. (2021) focus on the phytochemical and antibacterial properties of Rhoeo discolor, there is a notable debate and gap in how these complex physiological phenomena are translated into educational models. Shinde (2021) notes the microscopic appearance of Rhoeo discolor, highlighting its tightly packed pentagonal prism cells and purple cuticles, yet the literature predominantly treats these features as pharmacological or botanical data rather than pedagogical assets. This study critically engages with these sources by repurposing their botanical findings into an educational framework. This study is guided by the Inquiry-Based Learning (IBL) framework and the Constructivist Learning Theory. This framework posits that learners construct knowledge most effectively through direct observation, hands-on experimentation, and active problem-solving rather than passive reception of information (Fernando & Li, 2025; Lauss & Loparics, 2026). The selection of this framework is highly appropriate for the specific research problem because osmosis is an invisible force; therefore, students must observe its macroscopic effects on cells to construct a mental model of the process. By utilizing this framework, this research addresses the theoretical gap between abstract physiological concepts and concrete biological observation, contributing to the existing theory by providing a proven, visually striking experimental protocol.

The geographical and temporal context of this research is situated within the contemporary landscape of science education in regions with high biodiversity but limited advanced laboratory equipment, specifically in Madura, Indonesia, where this practicum was conducted. The case selection of Rhoeo discolor (oyster plant) is highly justified by its biological and contextual characteristics. Rhoeo discolor is an herbaceous perennial plant with brown fibrous roots, a round stem, and singular oval leaves characterized by a green upper surface and a distinct brownish-red or deep purple lower surface (Rahmayani et al., 2020). The purple color originates from anthocyanin, a water-soluble flavonoid compound (Shinde et al., 2021). A key challenge in local educational contexts is the lack of synthetic biological stains thus, the natural pigmentation of Rhoeo discolor perfectly bypasses this challenge, making it an ideal, accessible subject for microscopic observation.

Despite the extensive pharmacological exploration of Rhoeo discolor (Shinde et al., 2021) and the well-documented molecular mechanisms of plasmolysis in advanced botany (Harant & Lang, 2021), there is a distinct void in the literature concerning its empirical validation as a pedagogical tool specifically designed to support the 4MAT instructional model within the Merdeka Curriculum. Addressing this gap is crucial because educators need concrete, low-cost practical examples to bridge complex theoretical models (like 4MAT) with actual classroom execution (Firdaus et al., 2025). Addressing this specific gap is crucial because existing educational literature often lacks standardized, qualitative observational data on non-conventional plant models. By documenting the exact morphological and colorimetric changes during plasmolysis in Rhoeo discolor, this study directly fills this void, offering a scientifically validated and highly practical module for science educators worldwide. The primary research aim of this study is to qualitatively investigate the plasmolysis process in the epidermal tissue of Rhoeo discolor and to establish its viability as a visual pedagogical tool for teaching osmotic pressure in science education.

2. Research Methodology

2.1 Research Design

This study employed a qualitative descriptive research design, focusing on observational data rather than numerical measurements. The primary objective was to observe the structural and colorimetric changes in the epidermal cells of Rhoeo discolor before and after the administration of a hypertonic salt solution. The experimental framework was established with well-defined variables: the independent variable was the 10% NaCl concentration (5 grams of salt dissolved in 50 ml of water), the dependent variable was the observable change in the Rhoeo discolor epidermal cells, and the control variables included the Rhoeo discolor leaves, the salt, and the water.

2.2 Materials and Instruments

The primary biological specimen utilized in this study was the lower epidermal tissue of Rhoeo discolor leaves, selected for its distinct purple pigmentation. The chemical reagents consisted of neutral water, which served as the baseline testing solution, and a hypertonic sodium chloride (NaCl) solution to induce plasmolysis. Microscopic observations were conducted using a light microscope equipped with 4x and 10x objective lenses. Additional laboratory apparatus included object glasses, cover glasses, beaker glasses, measuring cylinders, an electric balance for precise weighing, razor blades for tissue sectioning, petri dishes, glass stirrers, dropper pipettes, and tissue paper for fluid management on the micro-slides.

2.3 Experimental Procedure

The experimental procedure commenced with the preparation of a 10% NaCl hypertonic solution, achieved by weighing 5 grams of salt using an electric balance, adding it to 50 ml of water in a beaker glass, and stirring until completely dissolved. Following the solution preparation, thin sections of the purple lower epidermis of the Rhoeo discolor leaf were carefully sliced using a razor blade. The tissue sample was mounted onto an object glass, hydrated with a single drop of water using a pipette, and

secured with a cover glass. This initial state was examined under the microscope at 4x and 10x magnifications, and the structural arrangement and pigmentation were documented.

To administer the treatment, a piece of tissue paper was placed at one edge of the cover glass to absorb the water by capillary action, while a single drop of the 10% NaCl solution was simultaneously applied to the opposite edge. The specimen was immediately re-examined under the microscope at the same magnifications. The morphological and color changes occurring within the epidermal cells were meticulously observed, drawn, and recorded.

2.4 Data Collection and Analysis

Data collection was strictly qualitative, relying on direct observation through the microscope. The analytical focus was directed toward two main descriptive parameters: the spatial density of the cells (whether they remained tightly packed or became loosely arranged) and the intensity of the cellular pigmentation (whether it remained deep purple or faded to pale). These observational data were systematically recorded in observation tables and supported by microscopic image documentation to validate the physiological occurrence of plasmolysis.

3. Result

The qualitative observations conducted at 4x and 10x magnifications revealed significant morphological and colorimetric changes in the Rhoeo discolor epidermal cells, depending on the type of solution administered. There were no experimental errors reported during the practicum, and the data obtained completely aligned with the initial research hypothesis.

3.1 Observation of Epidermal Cells in a Neutral Medium (Water)

When the Rhoeo discolor epidermal tissue was exposed to a single drop of neutral water, the cells exhibited a normal, turgid state. Under both 4x and 10x magnifications, the cellular arrangement appeared tightly packed, and the pigmentation was a deep purple. In this condition, the cells did not experience plasmolysis (Table 1). The visual evidence of this tightly packed, deep purple cellular structure can be seen in Fig. 1.

Table 1
Observation of Rhoeo discolor in water

Lens Magnification	Morphological Change	Color Change	Remarks
10x	Tightly packed	Deep purple	No plasmolysis occurred
4x	Tightly packed	Deep purple	No plasmolysis occurred

3.2 Observation of Epidermal Cells in a Hypertonic Medium (NaCl)

A stark contrast was observed upon the administration of one drop of 10% NaCl solution. Under both 4x and 10x magnifications, the cell structure transformed significantly; the previously tightly packed cells became loosely arranged, and the deep purple pigmentation faded into a pale color (Table 2). These morphological and colorimetric shifts indicated that the cells were undergoing plasmolysis. Figure 2 provides documentation of these changes at a 10x magnification.

Table 2
Observation of Rhoeo discolor in salt solution

Lens Magnification	Morphological Change	Color Change	Remarks
10x	Loosely arranged	Pale	Plasmolysis occurred
4x	Loosely arranged	Pale	Plasmolysis occurred

3.3 Physiological Confirmation of Plasmolysis

The results confirmed that plasmolysis in the Rhoeo discolor tissue was triggered by the addition of the hypertonic (concentrated) salt solution. Plasmolysis is defined as the detachment of the protoplasm from the plant cell wall due to the presence of a hypertonic medium. Because the NaCl solution has a higher solute concentration than the water inside the plant cells, the intracellular water was drawn out into the surrounding environment. This rapid loss of water caused the Rhoeo discolor epidermal cells to shrink and lose their vibrant color, thereby creating a loose spatial arrangement between the cells. Consequently, the experimental findings fully supported the hypothesis that water exits the cell toward a higher concentration environment, leading to cellular shrinkage and color loss.

4. Discussion

4.1 The Physiological Mechanism of Plasmolysis and Osmosis

The experimental results clearly demonstrated the occurrence of plasmolysis when the epidermal cells were exposed to a hypertonic medium, aligning with the theoretical principles of cellular osmosis. According to Nursita et al. (2020), osmosis is the movement of water molecules across a semipermeable membrane from an area of low concentration to an area of higher concentration, which generates osmotic pressure. This process is influenced by several factors, including the distance between solute and solvent, molecule size, temperature, the nature of the solute, and membrane thickness.

In this experiment, the 10% NaCl solution functioned as a highly concentrated hypertonic environment. In such conditions, a large proportion of water molecules become bound to the salt (the solute), leaving very few free water molecules capable of passing back through the cell membrane. Because intracellular water and minerals play a crucial role in cell metabolism, changes in osmotic pressure disrupt this balance, causing water to diffuse out of the cytoplasm. This massive efflux of water caused the plant cells to shrink significantly, pulling the protoplasm away from the cell wall and resulting in plasmolysis a state that, if prolonged, can lead to cell death. The initial hypothesis was successfully proven, as the intracellular water exited toward the high-concentration environment, causing the cells to shrink and lose their color.

4.2 Anatomical and Microscopic Characteristics of Rhoeo discolor

The distinct visual changes observed during the experiment are deeply rooted in the specific botanical and microscopic properties of Rhoeo discolor. Botanically, Rhoeo discolor (oyster plant) is a perennial herb characterized by a hidden, watery, round stem and single oval leaves that have a green upper surface and a distinct brownish-red or purple lower surface (Rahmayani et al., 2020).

Microscopically, Shinde (2020) notes that the epidermal cells of Rhoeo discolor leaves are thin-walled, contain a purple cuticle, and feature abundant oval stomata on the lower surface. These cells are naturally shaped like pentagonal prisms and are arranged in a tightly packed formation. This tightly packed pentagonal structure, combined with the deep purple pigmentation, was clearly visible during the initial observation in neutral water. However, once the cells lost water due to the hypertonic salt solution, the internal turgor pressure dropped, altering this precise geometric arrangement into a loosely packed and pale structure. Furthermore, physiological dynamics within these leaves, such as the opening and closing of stomata, are continuously influenced by external factors (sunlight intensity, CO_2 concentration, and abscisic acid) as well as internal factors (biological clocks, such as the release of ions at night that triggers stomatal closure).

4.3 Implications for Science Education: Visualizing Osmotic Pressure

A notable highlight of this practicum is that it was conducted without any experimental errors, yielding results that perfectly matched the theoretical hypothesis. From a pedagogical perspective, this reliability makes the experiment an exceptionally valuable tool for science education. The concept of osmotic pressure is inherently abstract and invisible to the naked eye; students often struggle to conceptualize water molecules moving across a semipermeable membrane (Rice et al., 2022).

By utilizing the lower epidermis of Rhoeo discolor, educators can transform this abstract concept into a vivid, observable phenomenon. The dramatic fading of the deep purple color to a pale hue, coupled with the structural shift from a tightly packed to a loosely arranged cell formation, provides concrete empirical evidence of water loss from the cellular vacuole. Consequently, this simple, low-cost

experimental design promotes inquiry-based learning, allowing students to visually confirm physiological theories and construct a deeper, more enduring understanding of plant cell dynamics (Thompson & Neebel, 2016; Koehler et al., 2020).

5. Conclusion

This study concludes that distinct morphological and colorimetric changes occur in the epidermal cells of Rhoeo discolor during plasmolysis. Prior to the administration of the salt solution, the epidermal cells exhibit a deep purple pigmentation and are densely packed. However, following the application of the salt solution, the cells lose their vibrant color, becoming pale, and their spatial arrangement becomes conspicuously loose. These observable changes signify the occurrence of plasmolysis, which is driven by the loss of intracellular water due to exposure to a concentrated or hypertonic environment. The primary causative factor for the plasmolysis observed in this experiment was the hypertonic nature of the salt solution, which actively drew the water out of the plant cells, leading to cellular shrinkage and the subsequent fading of the purple pigment. Beyond validating these physiological mechanisms, this study underscores the immense pedagogical value of this experiment. The striking visual contrast between the normal and plasmolyzed cells proves that Rhoeo discolor is an exceptional, highly accessible biological model for science education. By utilizing this simple experimental design, educators can successfully translate the abstract concept of osmotic pressure into a tangible, observable phenomenon, thereby significantly enhancing students' conceptual understanding of plant physiology.

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Figures

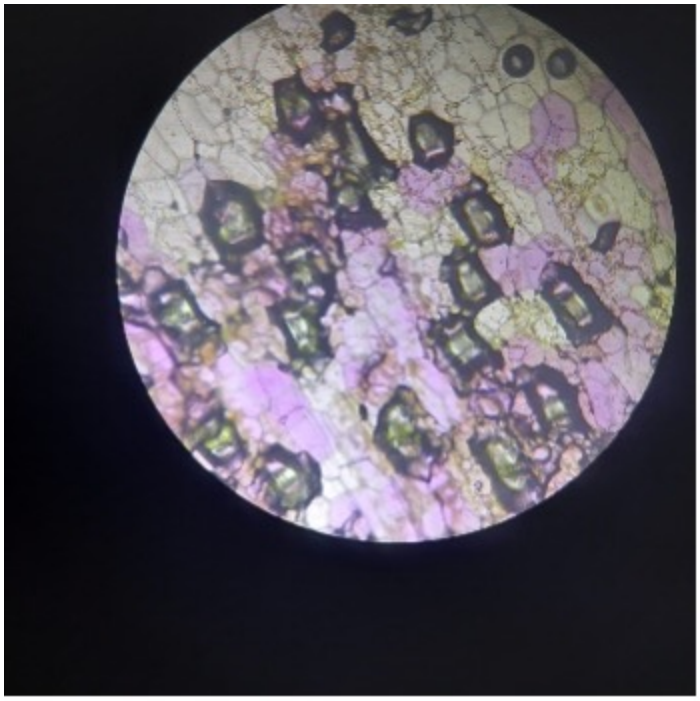

Figure 1

Documentation of Rhoeo discolor at 10x magnification before the administration of salt solution.

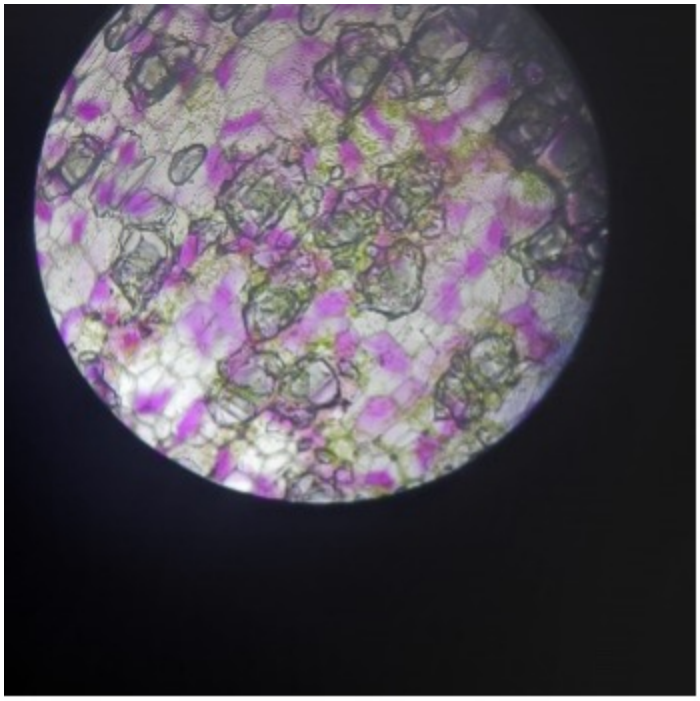

Figure 2

Documentation of Rhoeo discolor at 10x magnification after the administration of salt solution.