



PHOTOSYNTHESIS IN PLANTS: INTEGRATION OF CONCEPT MAPS AND EXPERIMENTAL ACTIVITIES

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ABSTRACT

This article presents a classroom-tested methodology for teaching photosynthesis in lower secondary biology through the combined use of concept maps and experimental activities. The approach answers a persistent challenge: many students memorize definitions yet fail to explain the mechanistic relationships among light, chloroplasts, pigments, water splitting, carbon fixation, oxygen release, and starch synthesis. Grounded in conceptual change theory, knowledge integration, and formative assessment, the intervention sequences lessons so that concept maps externalize prior ideas and guide inquiry, while practicals generate empirical evidence that is immediately reconciled on revised maps. The design was implemented over three to four 45-minute lessons using accessible materials: iodine starch tests on variegated leaves, carbon dioxide indicators for exploring gas exchange, and a leaf-disk assay to visualize oxygen evolution under different light conditions. Results indicate significant gains in mechanistic understanding, a reduction of common misconceptions (for example, “oxygen comes from carbon dioxide,” “plants photosynthesize at night,” or “plant mass comes from soil”), and improved ability to transfer ideas to novel contexts such as aquatic plants or shaded habitats.

KEYWORDS

Photosynthesis; concept maps; inquiry; experimental activities; conceptual change; formative assessment; secondary biology.

INTRODUCTION

Photosynthesis demands multilevel reasoning that connects molecular events to organismal function and ecological consequences. Learners often retain fragmented notions, treating chlorophyll as a “green substance that makes food” without specifying where light energy is captured or how carbon is fixed. Research repeatedly documents robust misconceptions and the limited effect of presentation-only lessons. Concept maps provide a structured representation of relationships and can surface naïve links before instruction. Experimental activities, in turn, can make otherwise invisible processes observable through proxy indicators such as color change, buoyancy, or starch deposition. When mapping and experimentation are orchestrated as a single learning design rather than as disconnected activities, students are positioned to propose causal links, test them, and then reconcile evidence with their models. The study aims to develop and evaluate a feasible methodology for grades 7–9 that integrates concept mapping with focused experiments to improve mechanistic understanding of photosynthesis. Specifically, it investigates whether the combined design enhances explanatory writing, corrects high-frequency misconceptions, and increases transfer to unfamiliar organisms and conditions when compared with mapping-only or experiment-only lessons.

The intervention was enacted in mixed-ability classes within regular timetables. Each unit began with an initial concept map constructed in small groups around seed terms such as light, chloroplast, water, carbon dioxide, glucose, oxygen, and stomata. Students connected terms with labeled propositions that expressed directionality and mechanism rather than mere association. The teacher collected maps to identify prevalent misconceptions and to plan targeted prompts.

Laboratory work followed immediately. In the iodine test, learners compared green and white sectors of variegated leaves that had been exposed to light, linking starch presence to chlorophyll distribution. A parallel set of leaves covered with foil demonstrated the dependence on light. To interrogate gas exchange, classes used a CO₂ indicator solution to contrast exhaled air with air from sealed plant chambers under light and dark conditions, discussing the interplay of photosynthesis and respiration. For a visible proxy of oxygen evolution, students carried out a leaf-disk assay: vacuum-infiltrated disks of spinach sank in bicarbonate solution and then rose as photosynthetic oxygen accumulated under illumination. Light intensity and wavelength were varied with distance and colored filters to elicit patterns that could be mapped back to pigment absorption and rate hypotheses.

Formative assessment was embedded throughout: exit slips demanded a single new proposition added to the map with evidence; mini-whiteboard graphs summarized leaf-disk rise times; and brief conferences pressed for mechanistic verbs in map links (absorbs, splits, diffuses, fixes). At the end of the sequence, students revised their maps and wrote a short explanation addressing the origin of oxygen and the fate of carbon. Learning was measured with a two-tier diagnostic instrument pairing multiple-choice items with open-ended justifications, a rubric for concept maps that scored proposition accuracy, hierarchy, and cross-links, and a writing rubric evaluating claim–evidence–reasoning. Statistical analysis compared pre/post scores within classes and examined associations between map quality and written explanations.

Students' initial maps revealed linear chains with vague links such as "light → chlorophyll → photosynthesis → food," often omitting water or misattributing oxygen to carbon dioxide. After the experiments, revised maps displayed more branched structures that connected the light-dependent reactions to water splitting and oxygen release, and the light-independent reactions to carbon fixation in the stroma. Learners began to articulate that oxygen detected by the indicator or inferred from leaf-disk buoyancy originated from water photolysis rather than from carbon dioxide. The iodine test anchored the idea that glucose is polymerized into starch in illuminated tissues and is absent where chlorophyll is missing or light is blocked, promoting an explicit link between pigment location and product formation.

Two-tier diagnostics showed significant pre/post gains, especially on items requiring explanation of daytime and nighttime gas exchange. Many students moved from the simplistic claim that "plants only photosynthesize" to balanced accounts that both photosynthesis and respiration occur, with relative dominance dependent on light. Written reasoning increasingly cited evidence, for example the faster rise of disks in red and blue filters than in green, and connected these observations to absorption spectra. Concept map scores correlated with explanation quality, suggesting that representational coherence supported clearer prose. Teachers reported that the combined design reduced off-task behavior and increased the

frequency of student-generated questions, particularly “what if” queries about light intensity and carbon dioxide concentration that advanced inquiry.

The integration also appeared to lower cognitive load. Because maps externalized the current model, students could update a single shared representation rather than juggling separate notes, graphs, and mental images. Experiments provided concrete anchors so that new links were not merely asserted but warranted. When misconceptions resurfaced—for instance, conflating gas bubbles with “air” rather than oxygen—the teacher revisited the indicator and asked students to reconcile results with their maps, reinforcing the norm that models must fit evidence. Importantly, the design worked in resource-constrained settings: when variegated leaves were unavailable, paper-masking on green leaves reproduced the logic of spatial contrast; when vacuuming disks was impractical, syringe infiltration or simple tram measurements of floating time still yielded interpretable differences.

Limitations included the short time window and variability in plant material quality, which affected assay sensitivity. Some groups initially treated maps as decorative webs; insisting on verb-labeled links and cross-links that compare photosynthesis and respiration corrected this drift. Future cycles should incorporate low-cost spectrophotometer alternatives or smartphone colorimetry to quantify pigment absorption, strengthening the bridge between observation and model.

Integrating concept maps with targeted experimental activities offers a coherent pathway for students to master photosynthesis as a mechanism rather than as a list of terms. Mapping surfaces prior ideas and organizes emerging explanations, while experiments supply salient, interpretable evidence that demands model revision. The combined approach improves diagnostic test performance, reduces entrenched misconceptions, and elevates the quality of mechanistic writing. It is feasible within ordinary school constraints and adaptable to local materials. Scaling the method calls for teacher professional learning focused on map facilitation, evidence-based discourse, and assessment rubrics that value explanatory links over recall. Extending the design to related units—cellular respiration, transpiration, and plant growth—can consolidate a systems view of plant physiology across the middle-grades curriculum.

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