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Improving Fourth-Grade Students' Conceptual Understanding of Photosynthesis Through Genially-Based Interactive Media: A Two-Cycle Classroom Action Research

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Abstract: This study aims to examine whether and how Genially-based interactive media supported fourth-grade students' conceptual understanding of photosynthesis across two classroom action research cycles. Twenty-one fourth-grade students in a public elementary school in Malang City, Indonesia, participated during the 2025-2026 school year, with Cycle I combining Genially with problem-based learning and Cycle II combining Genially with project-based learning that included direct plant observation, and conceptual understanding was measured with multiple-choice tests analyzed through normalized gain (N-Gain). In Cycle I, 42.86% of students were in the low N-Gain category and 57.14% were in the moderate category, and in Cycle II no student remained in the low category, 47.62% were in the moderate category, and 52.38% reached the high category, with an average N-Gain of 0.70. These findings suggest that guided use of Genially, combined with real-world observation activities and reflection-based revision, is associated with improved conceptual understanding of photosynthesis in this classroom, and the single-group design calls for cautious interpretation and further controlled research.

Keywords: Genially; interactive media; conceptual understanding; photosynthesis; classroom action research.

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INTRODUCTION

Photosynthesis is a core topic in school science because it links plant function, energy flow, and ecosystem processes, and learners at several educational levels have been reported to hold incomplete or inaccurate ideas about it. Barrutia and Díez (2021) examined 7- to 13-year-old students' understanding of plant nutrition and reported that children aged 8 to 9 showed a rudimentary understanding of photosynthesis with substantial conceptual flaws, and that children aged 10 to 11 described the role of the sun more precisely. Skribe Dimec and Strgar (2017) surveyed 427 primary school pupils aged 11 to 14 and reported misconceptions about the location of chlorophyll and photosynthesis in the plant and about energy transformation, with very little progress across grades. More recently, Kamarudin and Noor (2024) examined primary school children's understanding of photosynthesis through drawings and follow-up interviews and reported that understanding improved as children progressed through primary school.

Children's initial ideas serve as the starting point for instruction, and Rybska et al. (2017) reported that some ideas about the internal structure of trees persisted across age groups, which suggests that prior knowledge may resist change. Evidence on plant nutrition illustrates why this starting point matters, since Messig and Groß (2018) reported in a qualitative case study that students understood plant nutrition predominantly as the absorption of matter and often referred to their own diet when explaining it. The same study reported that the van Helmont experiment reinforced pre-instructional conceptions in this group of students, which indicates that an activity alone does not guarantee conceptual restructuring. Stagg and Verde (2019) reported that an educational theatre intervention improved primary students' comprehension of plant reproduction and their attitudes to plants, which shows that instruction designed around plant topics can support understanding.

Digital tools have been examined as one way to support the learning of abstract or hard-to-observe science content, as illustrated by the use of digital-media-based pedagogical aids in elementary entomology reported by Lu et al. (2022). Chueh and Cheng (2026) integrated a digital educational game into inquiry-based instruction in three fourth-grade classes and reported that it significantly enhanced students' conceptual understanding of insects, particularly for low-achieving students. Casanoves et al. (2023) assessed the ability of game-based science learning to enhance genetic understanding, which shows that conceptual understanding is a recurring outcome of interest in research on digital games for science. Teng et al. (2021) examined learning outcomes together with immersion experiences and visual attention distributions in a game for learning immunology, which suggests that the way learners interact with a digital medium is part of what shapes its effect.

Studies on digital media in science learning have reported varied patterns, and the conditions that surround a digital medium appear to matter. Pellas (2023) examined relationships among computational thinking skills, emotions, and cognitive load when fifth-grade students played a simulation game, which indicates that cognitive and

emotional conditions are examined alongside learning performance in primary education research on digital games. Pan and Ke (2023) investigated the effects of game-based learning supports on students' math performance and perceived game flow, which points to the role of support structures in game-based learning. Chen et al. (2023) examined adaptive scaffolding and engagement in digital game-based learning, which suggests that guided use of a digital medium is a relevant condition for examining its role in conceptual understanding.

Interactive and game-style features have received considerable attention in research on learning. Göksün and Gürsoy (2019) examined whether gamified quiz tools (Kahoot! and Quizizz) led to differences in academic achievement and student engagement compared with a control condition and reported more positive outcomes for the experimental groups. Hamari et al. (2016) surveyed 173 players of two learning games and reported that engagement had a clear positive effect on learning and that challenge predicted learning both directly and through engagement. Licorish et al. (2018) interviewed university students about Kahoot! and reported that it influenced classroom dynamics, engagement, and motivation, with timely feedback and well-integrated content identified as contributing factors. Genially is a web-based platform for building interactive presentations, visuals, and game-style activities, and these features offer a practical route for introducing quiz and game elements into primary science lessons.

The instructional model that accompanies digital media can shape how students use it. Lonergan et al. (2022) examined problem-based learning in 10 mainstream Grade 8 classrooms in a quasi-experimental study and asked whether it was effective for all students, including identified groups of exceptional learners. Krajcik et al. (2023) evaluated a project-based science intervention in elementary schools and reported that third graders in the intervention scored higher on a standardized science test than comparison students. Atchia et al. (2022) reported a case study that used design thinking to identify and clear students' misconceptions in photosynthesis, which shows that classroom-based efforts to improve photosynthesis instruction continue to be reported.

Preliminary interviews and observations in a fourth-grade class at a public elementary school in Malang City, Indonesia, indicated that science lessons relied on conventional methods and workbooks. Students were passive during lessons, and many were unable to explain photosynthesis coherently. Several students held misconceptions about the role of the sun and the plant parts involved in photosynthesis. These conditions are relevant to the Indonesian elementary curriculum, in which science is taught as part of the integrated subject *Ilmu Pengetahuan Alam dan Sosial* (IPAS, Natural and Social Sciences), and they called for instructional media that make the process visible and interactive.

Existing studies have documented children's and students' conceptions of photosynthesis and plant nutrition and have examined digital tools and games in several science topics, and less attention has been directed toward how a web-based interactive platform such as Genially, implemented in successive action research cycles with different instructional models, relates to primary school students' conceptual

understanding of photosynthesis in Indonesian classrooms. This study aims to examine whether and how Genially-based interactive media, used with problem-based learning in Cycle I and project-based learning in Cycle II, is associated with changes in fourth-grade students' conceptual understanding of photosynthesis. This study extends previous research by documenting, within one classroom, the distribution of N-Gain categories across two cycles together with the reflections that guided the revision from Cycle I to Cycle II, which provides practical evidence for teachers in similar contexts.

This study is guided by the following research questions: 1) How are fourth-grade students distributed across N-Gain categories for photosynthesis after Cycle I, in which Genially was combined with problem-based learning? 2) How are students distributed across N-Gain categories after Cycle II, in which Genially was combined with project-based learning and direct plant observation? 3) How did the revisions made after the Cycle I reflection relate to the change in students' N-Gain categories from Cycle I to Cycle II? 4) What patterns of student engagement and implementation challenges were observed across the two cycles?

METHODS

Research Design

This study employed classroom action research with two cycles, and each cycle consisted of planning, implementation, observation, and reflection. Action research is a cyclical process of intervention and reflection in which findings from one cycle inform the design of the next, and Domingos-Grilo et al. (2012) used an action-research programme to improve the teaching and learning of photosynthesis. Planning involved interviews and discussions between the researcher and the classroom teacher about difficult material, followed by the development of lesson plans, media, and assessment questions. Implementation, observation, and reflection were carried out collaboratively, and the reflection from Cycle I was used to revise the design of Cycle II.

Participants and Setting

The study was conducted in a fourth-grade class at a public elementary school in Malang City, East Java, Indonesia, during the 2025-2026 school year. The participants were 21 fourth-grade students, and the whole study lasted approximately one month. The classroom teacher collaborated with the researcher in planning, delivering, and reflecting on the lessons. Preliminary interviews and observations were used to identify the learning problem before the first cycle.

The study involved a single class of 21 students and two cycles of approximately two class periods each. This bounded classroom context defines the scope of the findings. The two cycles differed in instructional model and learning location, which is important for interpreting the changes between Cycle I and Cycle II.

Table 1. Summary of the Research Design

Component	Description
Approach	Classroom action research with two cycles
Setting	Fourth-grade class, public elementary school, Malang City, Indonesia

Participants	21 fourth-grade students, 2025-2026 school year
Duration	Approximately one month
Cycle stages	Planning, implementation, observation, reflection
Cycle I	Genially-based media with problem-based learning (PBL), in-class, 2 class periods
Cycle II	Genially-based media with project-based learning (PjBL), in-class and out-of-class, 2 class periods
Data sources	Pre-test, Post-test I, Post-test II, interviews, classroom observation
Data analysis	Normalized gain (N-Gain), N-Gain categories, percentage of students per category

Intervention and Procedure

In Cycle I, Genially-based interactive media was used with the problem-based learning model and case studies on global issues, and the lesson was delivered in the classroom over two class periods. Students completed a pre-test before the intervention and worked on student worksheets (*Lembar Kerja Peserta Didik*, LKPD) designed for problem-based learning, in which they analyzed problems related to photosynthesis and proposed solutions. Students presented their results in front of the class, and Post-test I was administered at the end of the lesson. The teaching module (*Modul Ajar*) was identical in both cycles, and only the worksheet activities differed.

In Cycle II, Genially-based media was used with the project-based learning model, and the lesson combined in-class and out-of-class activities over two class periods. The stimulus for the project was taken from the students' real-world environment, and the worksheets used a project-based approach. Students observed plants located indoors and outdoors, compared plant conditions in the two locations, and identified the factors that influenced those conditions. A post-test with 20 multiple-choice items aligned with the learning indicators was administered at the end of Cycle II.

Figure 1 illustrates the two-cycle classroom action research procedure, including the planning, implementation, observation, and reflection stages. It also indicates the administration of the pre-test, Post-test I, and Post-test II, as well as the role of Cycle I reflection in informing the revision of Cycle II.

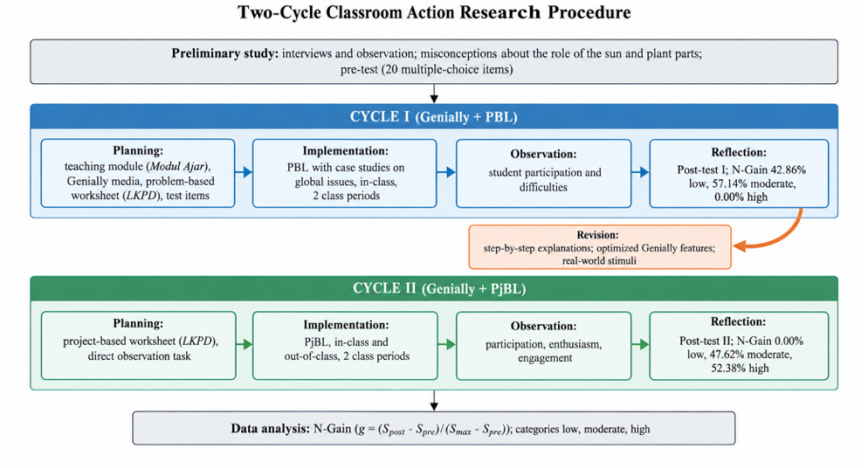


Figure 1. Two-cycle classroom action research procedure

Figure 1 shows that Cycle I combined Genially with problem-based learning and concluded with Post-test I and a reflection stage. The reflection informed the implementation of Cycle II, which combined Genially with project-based learning and direct plant observation. Post-test II was administered at the end of Cycle II, followed by a final reflection. The intervention therefore involved several changes between cycles that should be considered when interpreting the N-Gain results.

Figure 2 presents the interface of the Genially-based interactive learning media used in the lessons. The media incorporated interactive visual materials and game-style activities to support students' engagement with photosynthesis content.



Figure 2. Interface of the Genially-based interactive learning media on photosynthesis

Figure 2 shows the interactive layout through which students accessed the photosynthesis material and completed digital game-style activities during the lessons.

Instruments

The variable examined was the improvement in fourth-grade students' conceptual understanding of photosynthesis, which was measured through a multiple-choice test administered in three stages. The pre-test was administered before the intervention to assess students' initial understanding, Post-test I was administered after Cycle I, and Post-test II was administered after Cycle II. The pre-test and Post-test II each consisted of 20 multiple-choice items aligned with the learning indicators. Interviews and classroom observations provided supporting information about students' prior misconceptions, participation, and engagement.

Data Analysis

Data were analyzed quantitatively using normalized gain (N-Gain), which expresses the actual gain as a proportion of the maximum possible gain. Following Hake (1998), N-Gain was calculated as g = (S_post - S_pre) / (S_max - S_pre), where S_post is the post-test score, S_pre is the pre-test score, and S_max is the maximum score. Each student's N-Gain was classified using the criteria in Table 2, and the percentage of students in each category was calculated for Cycle I (pre-test to Post-test I) and Cycle II (pre-test to Post-test II). The indicators of success were an average N-Gain in the moderate or high category, an increase in conceptual understanding from Cycle I to Cycle II, and increased student activity and engagement during learning.

Table 2. N-Gain Score Criteria

N-Gain value (g)	Category
$0.70 \leq g \leq 1.00$	High
$0.30 \leq g < 0.70$	Moderate
$0.00 \leq g < 0.30$	Low

N-Gain values below 0.30 were classified as low, values from 0.30 to below 0.70 as moderate, and values from 0.70 to 1.00 as high, following the criteria reported by Hake (1998). The classification accounts for the maximum possible improvement relative to students' pre-test scores. The reported average N-Gain of 0.70 falls at the lower boundary of the high category.

RESULTS

Preliminary Conditions

Interviews and observations conducted before the action research showed that misconceptions about photosynthesis persisted in the class. Students had not yet fully understood the material, and the absence of interactive teaching aids was associated with low motivation during lessons. Many students could not explain the process of photosynthesis coherently, and some held misconceptions about the role of the sun and the plant parts involved. These conditions were consistent with suboptimal learning outcomes and provided the basis for the intervention in Cycle I.

Implementation of the Actions

Table 3 compares the teaching tools and the implementation of Cycle I and Cycle II.

Table 3. Comparison of Teaching Tools and Implementation in Cycle I and Cycle II

Component	Cycle I	Cycle II
Teaching module (*Modul Ajar*)	Used	Used (identical to Cycle I)
Student worksheet (LKPD), problem-based	Used	Not used
Student worksheet (LKPD), project-based	Not used	Used
Learning medium	Genially-based interactive media	Genially-based interactive media
Duration	2 class periods	2 class periods
Learning location	In-class	In-class and out-of-class
Instructional model	Problem-based learning (PBL)	Project-based learning (PjBL)
Problem prompts	Infographics	Direct observation
Worksheet focus	Analyzing photosynthesis-related problems based on case studies on global issues	Observing plants indoors and outdoors, comparing plant conditions, and identifying influencing factors

Note. LKPD = Lembar Kerja Peserta Didik (student worksheet).

The teaching module remained identical across cycles, whereas the worksheets, instructional model, learning location, and problem prompts changed. Cycle I used

infographic-based problem prompts and in-class analysis, whereas Cycle II incorporated direct observation of plants in indoor and outdoor locations. Because Genially was used in both cycles, the comparison reflects the combined changes in instructional model, learning activities, and context. The N-Gain differences should therefore be interpreted in relation to the overall revised cycle design.

In Cycle I, students completed the pre-test, analyzed problems in the problem-based worksheets, and presented their results, and this activity served to train their ability to understand concepts. Some students had not yet achieved optimal results after this cycle. The problems presented in the worksheets were abstract and not yet connected to students' experiences, so students had difficulty linking photosynthesis to the situations in the worksheets. In Cycle II, students conducted direct observations of plants indoors and outdoors, which allowed them to see differences in plant conditions across locations and to identify the factors involved.

Conceptual Understanding Outcomes

Table 4 presents the number and percentage of students in each N-Gain category after Cycle I and Cycle II.

Table 4. *Distribution of N-Gain Categories by Cycle (N = 21)*

Category	Cycle I (n)	Cycle I (%)	Cycle II (n)	Cycle II (%)
Low ($g < 0.30$)	9	42.86	0	0.00
Moderate ($0.30 \leq g < 0.70$)	12	57.14	10	47.62
High ($g \geq 0.70$)	0	0.00	11	52.38
Total	21	100.00	21	100.00

Note. Student counts were derived from the reported percentages and the class size. The reported average N-Gain score was 0.70, which falls into the high category.

In Cycle I, 9 students (42.86%) were in the low category and 12 students (57.14%) were in the moderate category, with no students in the high category. In Cycle II, no students remained in the low category, 10 students (47.62%) were in the moderate category, and 11 students (52.38%) were in the high category. This distribution indicates an overall shift toward higher N-Gain categories between the two cycles.

Figure 3 compares the distribution of N-Gain categories in Cycle I and Cycle II as a grouped bar chart.

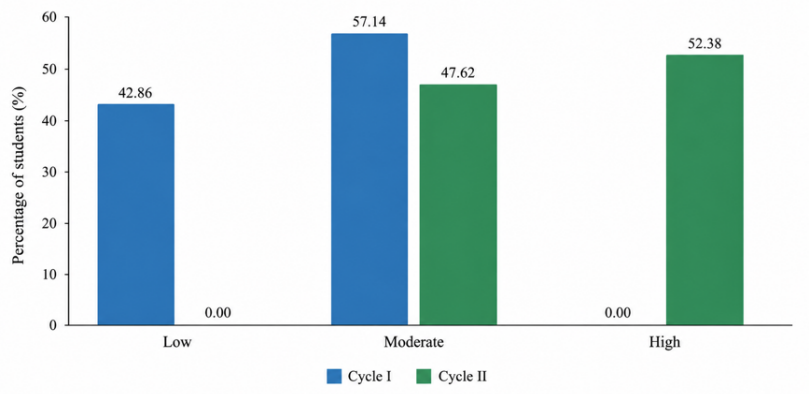


Figure 3. Comparison of N-Gain category distribution in Cycle I and Cycle II

Figure 3 shows that the proportion of students in the low category decreased from 42.86% in Cycle I to 0.00% in Cycle II. The moderate category decreased from 57.14% to 47.62%, while the high category increased from 0.00% to 52.38%. These changes indicate an upward shift in the class distribution following the Cycle II revisions. The pattern is consistent with improved conceptual understanding within this classroom, although the combined changes between cycles prevent attribution of the improvement to a single intervention component.

In Cycle I, the intervention was associated with moderate gains for most students (57.14%), and 42.86% remained in the low category, which indicates that the improvement was not yet optimal. In Cycle II, the corrective actions were associated with a distribution without students in the low category. The average N-Gain score of 0.70 falls into the high category, which indicates a considerable improvement in conceptual understanding after the instruction. These results show that students understood the material better after the interventions than before them.

Student Engagement

Observations in Cycle I and Cycle II showed differences in student participation. Participation increased in discussions, in answering questions, and in completing assigned tasks. Students showed greater enthusiasm and more active engagement than at the early stages of learning. These observations are descriptive and were not quantified with a scored observation instrument.

Reflection on the Actions

Table 5 summarizes the reflections recorded after Cycle I and Cycle II.

Table 5. Reflection Findings and Follow-Up Actions in Cycle I and Cycle II

Aspect	Cycle I	Cycle II
Instructional model	PBL with Genially	PjBL with Genially
N-Gain categories	42.86% low, 57.14% moderate, 0.00% high	0.00% low, 47.62% moderate, 52.38% high
Student engagement	Attention captured; students more enthusiastic and active than in earlier sessions	Students more active and enthusiastic; concepts grasped more concretely and material understood more easily
Main reflection	Learning not yet optimal because of confusion about the platform, lack of focus, time management, and abstract problems	Students had become accustomed to the learning model, and engagement, participation, and understanding increased
Follow-up action	Simpler step-by-step explanations; optimized use of Genially features; real-world stimuli	Clearer instructions, improved classroom management, and more discussion and practice

The main difficulties in Cycle I concerned platform use, student focus, time management, and the abstract nature of the problems. The follow-up actions addressed these difficulties through step-by-step explanations, optimized use of Genially features, and real-world stimuli based on direct plant observation. In Cycle II, the reflection

recorded higher engagement and improved conceptual understanding, alongside the absence of students in the low N-Gain category. These findings document how classroom reflection informed the revisions implemented in the second cycle.

DISCUSSION

Student Distribution Across N-Gain Categories After Cycle I (RQ1)

In Cycle I, 9 students (42.86%) were in the low category and 12 students (57.14%) were in the moderate category, which indicates that the improvement was not yet optimal. Villanueva et al. (2021) analyzed young children's drawings of the plant world in a cohort study and reported changes in pictorial content over time, which shows that children's representations of plants shift as they grow. Amprazis et al. (2021) reported that primary school children did not spontaneously recall plants as living things, which indicates that basic ideas about plants can be incomplete even before photosynthesis is taught. Because the present study analyzed gains in total test scores without a misconception-specific diagnostic, the improvement is best read as general conceptual progress, and future studies should add diagnostic items that track specific conceptions.

The Cycle I results, in which 42.86% of students remained in the low category, can be explained by two difficulties recorded during reflection: unfamiliarity with the platform and problems that were abstract and distant from students' experience. Chang et al. (2018) compared digital game-based learning with computer-based learning among college students and reported that learning achievement and flow were positively related and that both were negatively related to overall cognitive load, so a new platform combined with abstract problems may have consumed capacity needed for learning photosynthesis. Sotiriou et al. (2020) examined how inquiry-based learning combined with e-learning can serve high and low achievers, which is relevant to the Cycle I decision to provide simpler, step-by-step explanations. This interpretation is inferential because cognitive load was not measured, and it suggests that teachers who introduce an interactive platform should allocate time for orientation and break tasks into manageable steps.

Student Distribution Across N-Gain Categories After Cycle II (RQ2)

The main finding of this study is that students' N-Gain categories for photosynthesis moved from a Cycle I distribution of 42.86% low and 57.14% moderate to a Cycle II distribution of 47.62% moderate and 52.38% high, with an average N-Gain of 0.70. This pattern suggests that the class as a group gained a larger share of the possible improvement after the second cycle. Cheng et al. (2024) combined educational gaming with physical experiments to engage high school students in inquiry-based learning, and the pairing of a digital medium with direct plant observation in Cycle II of the present study follows a comparable instructional direction even though the subject, level, and design differ. This comparison is indicative only, because the cited study involved high school students and the present study involved one primary classroom without a comparison group.

Different patterns have been reported for digital and game-based media across science topics. Hwang and Chen (2017) examined an inquiry-based ubiquitous gaming design in relation to students' learning achievements, motivation, behavioral patterns, and tendency toward critical thinking and problem solving, which is conceptually close to the combination of a digital medium and inquiry-style activity used here. The average N-Gain of 0.70 lies at the lower boundary of the high category, which calls for cautious reading of the Cycle II result. The absence of students in the low category is a descriptive pattern that applies to this class only.

Revisions After the Cycle I Reflection and the Change Between Cycles (RQ3)

The larger gains in Cycle II coincided with a change from problem-based learning to project-based learning that used direct observation of plants. Aditomo and Klieme (2020) examined forms of inquiry-based science instruction and their relations with learning outcomes in high- and low-performing education systems, which indicates that the way inquiry is organized in a classroom is linked to what students learn. Al-nakhle (2022) reported in a randomized quasi-experimental study that scenario-based virtual laboratory simulations improved learning outcomes and scientific report writing skills, which is compatible with the Cycle II combination of a digital medium and hands-on observation. Because the instructional model, the learning location, the teacher's classroom management, and students' familiarity with the platform all changed between cycles, the findings should be interpreted in relation to the whole revised design and cannot be attributed to Genially alone.

The Cycle II revisions included clearer instructions, improved classroom management, and more discussion and practice, which means that teacher orchestration formed part of the revised design. Arias et al. (2016) examined how teachers used educative curriculum materials to engage students in science practices, which is relevant here because Genially was used inside teacher-guided lessons. van Uum et al. (2017) examined scaffolding of pupils' self-directed learning in open inquiry, which implies that the benefit of Genially depends on teacher preparation and orchestration in addition to the platform itself. Teachers who plan to use interactive media for abstract topics such as photosynthesis can introduce the platform with a short orientation, provide step-by-step guidance, and connect digital activities to observation of plants in the school environment, an approach consistent with Nichols et al. (2017), who compared two inquiry professional development interventions in science in relation to primary students' questioning and other inquiry behaviors.

Student Engagement and Implementation Challenges (RQ4)

Li et al. (2024) reported that learning engagement mediated the relation between digital educational games and students' motivation for learning, and the observed increases in discussion, questioning, and task completion in the present study mainly reflect the behavioral side of engagement. Koć-Januchta et al. (2020) investigated students' interaction and learning with an artificial intelligence-enriched biology textbook built around asking questions, which is relevant to the increased questioning and discussion observed here. Cheng et al. (2017) examined whether and to what extent game immersion

during serious gaming affects science learning, which suggests that engagement benefits depend on implementation context. Ellwood and Abrams (2018) linked experiences of flow in inquiry-based science education to motivation and achievement, and this is relevant to the way teacher-linked, quiz-style activities in Genially may support learning.

The main implementation challenges recorded in Cycle I were confusion about the platform, lack of focus, time management, and abstract problems. By Cycle II, students had become accustomed to the learning model, and the reflection recorded higher engagement, participation, and understanding. These observations suggest that a short orientation to the platform and clear task steps are practical conditions for using interactive media in primary science. School leaders and teacher educators can use the cycle-based documentation in Tables 3 and 5 as a template for professional learning in schools with similar resources.

Limitations

Cycle II gains were calculated from the same pre-test as Cycle I, and Agarwal (2019) reported that retrieval practice with quizzes increased delayed test performance relative to rereading or no quizzes, so repeated testing across the cycles may have contributed to the higher Cycle II gains. Tytler et al. (2020) showed that conclusions about conceptual understanding depend on the representational forms an assessment allows, and Andersson et al. (2020) and Torkar et al. (2019) reported that drawings, explanations, and written responses convey different information, so the multiple-choice test may not capture all aspects of understanding. The study involved one class of 21 students without a control group, so causal claims about Genially are not supported, and test validity and reliability indices, individual scores, and a scored engagement instrument were not reported.

CONCLUSION

This study examined whether and how Genially-based interactive media supported fourth-grade students' conceptual understanding of photosynthesis across two classroom action research cycles. In Cycle I, which combined Genially with problem-based learning, most students reached a moderate N-Gain category and a substantial share remained in the low category, so the improvement was not yet optimal. In Cycle II, which combined Genially with project-based learning and direct plant observation, no student remained in the low category and the class distribution shifted toward the moderate and high categories, with an average N-Gain in the high category. The revisions made after the Cycle I reflection, namely simpler step-by-step explanations, optimized use of Genially features, and real-world stimuli based on direct observation, coincided with this upward shift, together with higher participation in discussions, questioning, and task completion and fewer implementation difficulties. These findings indicate that guided use of Genially, project-based observation activities, and reflection-based revision were associated with improved conceptual understanding in this classroom, and the single-class design and the combined changes between cycles mean that the findings describe an association within this context. Teachers who adopt similar media can plan an orientation to the platform, provide stepwise guidance, and link digital activities to direct

observation of plants, and future studies can add comparison groups, delayed post-tests, misconception-specific diagnostics, and quantified engagement measures.

AI Use Statement

AI-assisted tools were used, where applicable, for language refinement and proofreading. The authors reviewed the manuscript and take responsibility for its content.

Author Contributions

PR: conceptualization, research design, data collection, data analysis, and initial manuscript preparation. NY: research methodology, supervision, data interpretation, and manuscript revision. ASS: classroom implementation, observation, and data collection. NOS: critical review, interpretation of findings, and manuscript editing. All authors approved the final manuscript.

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Conflict of Interest

The authors declare no competing interests.

REFERENCES

Aditomo, A., & Klieme, E. (2020). Forms of inquiry-based science instruction and their relations with learning outcomes: Evidence from high and low-performing education systems. *International Journal of Science Education, 42*(4), 504–525. https://doi.org/10.1080/09500693.2020.1716093

Agarwal, P. K. (2019). Retrieval practice & Bloom's taxonomy: Do students need fact knowledge before higher order learning? *Journal of Educational Psychology, 111*(2), 189–209. https://doi.org/10.1037/edu0000282

Al-nakhle, H. (2022). The effectiveness of scenario-based virtual laboratory simulations to improve learning outcomes and scientific report writing skills. *PLOS ONE, 17*(11), Article e0277359. https://doi.org/10.1371/journal.pone.0277359

Amprazis, A., Papadopoulou, P., & Malandrakis, G. (2021). Plant blindness and children's recognition of plants as living things: A research in the primary schools context. *Journal of Biological Education, 55*(2), 139–154. https://doi.org/10.1080/00219266.2019.1667406

Andersson, J., Löfgren, R., & Tibell, L. A. E. (2020). What's in the body? Children's annotated drawings. *Journal of Biological Education, 54*(2), 176–190. https://doi.org/10.1080/00219266.2019.1569082

Arias, A. M., Davis, E. A., Marino, J.-C., Kademian, S. M., & Palincsar, A. S. (2016). Teachers' use of educative curriculum materials to engage students in science practices. *International Journal of Science Education, 38*(9), 1504–1526. https://doi.org/10.1080/09500693.2016.1198059

Atchia, S. M. C., Chummun, D., & Luckho, S. (2022). Use of design thinking as a strategy to identify and clear students' misconceptions in photosynthesis: A case study. *Journal of Biological Education, 58*(3), 666–683. https://doi.org/10.1080/00219266.2022.2100452

Barrutia, O., & Díez, J. R. (2021). 7 to 13-year-old students' conceptual understanding of plant nutrition: Should we be concerned about elementary teachers' instruction? *Journal of Biological Education, 55*(2), 196–216. https://doi.org/10.1080/00219266.2019.1679655

Casanoves, M., Solé-Llussà, A., Haro, J., Gericke, N., & Valls, C. (2023). Assessment of the ability of game-based science learning to enhance genetic understanding. *Research in Science & Technological Education, 41*(4), 1496–1518. https://doi.org/10.1080/02635143.2022.2044301

Chang, C.-C., Warden, C. A., Liang, C., & Lin, G.-Y. (2018). Effects of digital game-based learning on achievement, flow and overall cognitive load. *Australasian Journal of Educational Technology, 34*(4), 155–167. https://doi.org/10.14742/ajet.2961

Chen, C.-H., Law, V., & Huang, K. (2023). Adaptive scaffolding and engagement in digital game-based learning. *Educational Technology Research and Development, 71*(4), 1785–1798. https://doi.org/10.1007/s11423-023-10244-x

Cheng, M.-T., Lin, Y.-W., She, H.-C., & Kuo, P.-C. (2017). Is immersion of any value? Whether, and to what extent, game immersion experience during serious gaming affects science learning. *British Journal of Educational Technology, 48*(2), 246–263. https://doi.org/10.1111/bjet.12386

Cheng, M.-T., Chou, W.-C., Hsu, M.-E., & Cheng, F.-C. (2024). Blending educational gaming with physical experiments to engage high school students in inquiry-based learning. *Journal of Biological Education, 58*(5), 1517–1536. https://doi.org/10.1080/00219266.2022.2157861

Chueh, C.-J., & Cheng, M.-T. (2026). Integrating a digital educational game into inquiry-based instruction: Effects on fourth-grade students' science learning and questioning. *Journal of Science Education and Technology, 35*(2), 481–496. https://doi.org/10.1007/s10956-025-10261-w

Domingos-Grilo, P., Reis-Grilo, C., Ruiz, C., & Mellado, V. (2012). An action-research programme with secondary education teachers on teaching and learning photosynthesis. *Journal of Biological Education, 46*(2), 72–80. https://doi.org/10.1080/00219266.2011.587522

Ellwood, R., & Abrams, E. (2018). Student's social interaction in inquiry-based science education: How experiences of flow can increase motivation and achievement. *Cultural Studies of Science Education, 13*, 395–427. https://doi.org/10.1007/s11422-016-9769-x

Göksün, D. O., & Gürsoy, G. (2019). Comparing success and engagement in gamified learning experiences via Kahoot and Quizizz. *Computers & Education, 135*, 15–29. https://doi.org/10.1016/j.compedu.2019.02.015

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74. https://doi.org/10.1119/1.18809

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045

Hwang, G.-J., & Chen, C.-H. (2017). Influences of an inquiry-based ubiquitous gaming design on students' learning achievements, motivation, behavioral patterns, and tendency towards critical thinking and problem solving. *British Journal of Educational Technology, 48*(4), 950–971. https://doi.org/10.1111/bjet.12464

Kamarudin, M. Z., & Noor, M. S. A. M. (2024). To what extent do primary school children understand photosynthesis? A study of children's drawings with follow-up interviews. *Education 3-13*. https://doi.org/10.1080/03004279.2024.2385434

Koć-Januchta, M. M., Schönborn, K. J., Tibell, L. A. E., Chaudhri, V. K., & Heller, H. C. (2020). Engaging with biology by asking questions: Investigating students' interaction and learning with an artificial intelligence-enriched textbook. *Journal of Educational Computing Research, 58*(6), 1190–1224. https://doi.org/10.1177/0735633120921581

Krajcik, J., Schneider, B., Miller, E. A., Chen, I.-C., Bradford, L., Baker, Q., Bartz, K., Miller, C., Li, T., Codere, S., & Peek-Brown, D. (2023). Assessing the effect of project-based learning on science learning in elementary schools. *American Educational Research Journal, 60*(1), 70–102. https://doi.org/10.3102/00028312221129247

Li, Y., Chen, D., & Deng, X. (2024). The impact of digital educational games on student's motivation for learning: The mediating effect of learning engagement and the moderating

effect of the digital environment. *PLOS ONE, 19*(1), Article e0294350. https://doi.org/10.1371/journal.pone.0294350

Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning, 13*, Article 9. https://doi.org/10.1186/s41039-018-0078-8

Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the efficacy of problem-based learning in diverse secondary school classrooms: Characteristics and goals of problem-based learning. *International Journal of Educational Research, 112*, Article 101945. https://doi.org/10.1016/j.ijer.2022.101945

Lu, S.-J., Chen, Y.-H., Huang, H., & Liu, Y.-C. (2022). The role of digital-media-based pedagogical aids in elementary entomology: An innovative and sustainable approach. *Sustainability, 14*(16), Article 10067. https://doi.org/10.3390/su141610067

Messig, D., & Groß, J. (2018). Understanding plant nutrition: The genesis of students' conceptions and the implications for teaching photosynthesis. *Education Sciences, 8*(3), Article 132. https://doi.org/10.3390/educsci8030132

Nichols, K., Burgh, G., & Kennedy, C. (2017). Comparing two inquiry professional development interventions in science on primary students' questioning and other inquiry behaviours. *Research in Science Education, 47*(1), 1–24. https://doi.org/10.1007/s11165-015-9487-5

Pan, Y., & Ke, F. (2023). Effects of game-based learning supports on students' math performance and perceived game flow. *Educational Technology Research and Development, 71*(2), 459–479. https://doi.org/10.1007/s11423-022-10183-z

Pellas, N. (2023). Exploring relationships among students' computational thinking skills, emotions, and cognitive load using simulation games in primary education. *Journal of Computer Assisted Learning, 39*(5), 1576–1590. https://doi.org/10.1111/jcal.12819

Rybska, E., Tunnicliffe, S. D., & Sajkowska, Z. A. (2017). Children's ideas about the internal structure of trees: Cross-age studies. *Journal of Biological Education, 51*(4), 375–390. https://doi.org/10.1080/00219266.2016.1257500

Skribe Dimec, D., & Strgar, J. (2017). Scientific conceptions of photosynthesis among primary school pupils and student teachers of biology. *CEPS Journal, 7*(1), 49–68. https://doi.org/10.26529/cepsj.14

Sotiriou, S. A., Lazoudis, A., & Bogner, F. X. (2020). Inquiry-based learning and e-learning: How to serve high and low achievers. *Smart Learning Environments, 7*, 1–15. https://doi.org/10.1186/s40561-020-00130-x

Stagg, B. C., & Verde, M. F. (2019). Story of a seed: Educational theatre improves students' comprehension of plant reproduction and attitudes to plants in primary science education. *Research in Science & Technological Education, 37*(1), 15–35. https://doi.org/10.1080/02635143.2018.1455655

Teng, Y. Y., Chou, W. C., & Cheng, M.-T. (2021). Learning immunology in a game: Learning outcomes, the use of player characters, immersion experiences and visual attention distributions. *Journal of Computer Assisted Learning, 37*(2), 475–486. https://doi.org/10.1111/jcal.12501

Torkar, G., Gnidovec, T., Tunnicliffe, S. D., & Tomažič, I. (2019). Assessing students' knowledge of owls from their drawings and written responses. *Journal of Biological Education, 53*(1), 54–62. https://doi.org/10.1080/00219266.2017.1420682

Tytler, R., Prain, V., Aranda, G., Ferguson, J., & Gorur, R. (2020). Drawing to reason and learn in science. *Journal of Research in Science Teaching, 57*(2), 209–231. https://doi.org/10.1002/tea.21590

van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2017). Inquiry-based science education: Scaffolding pupils' self-directed learning in open inquiry. *International Journal of Science Education, 39*(18), 2461–2481. https://doi.org/10.1080/09500693.2017.1388940

Villanueva, X., Villarroel, J. D., & Antón, A. (2021). Young children's drawings of plant world: A cohort study analysing pictorial content. *Journal of Biological Education, 55*(3), 225–237. https://doi.org/10.1080/00219266.2019.1679656