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Digital Science Learning with Wordwall to Enhance Students' Cognitive Learning Outcomes on Ecosystem Concepts through Discovery Learning

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Abstract
This study presents a comprehensive literature review on the concept of ecosystems and their influence on students' science learning. Low student achievement in science subjects, particularly in abstract concepts, remains a major issue in many elementary schools in Indonesia. The dominance of lecture-based teaching methods causes students to experience difficulties in processing information and increases cognitive load, thereby necessitating more interactive media innovations. Based on these conditions, this study aims to analyze the effect of using the website-based Wordwall application on the science learning outcomes of fifth-grade elementary school students. This quantitative study employed a quasi-experimental design (non-equivalent control group design) and involved 61 students. The learning outcome test instruments (pretest–posttest) were tested for validity and reliability. Data analysis was conducted using the Mann–Whitney U test because the assumption of homogeneity was not met (Levene's Sig. < .001). Descriptively, the experimental group experienced a significant increase in mean scores, from 30 to 85 (an increase of 55 points), far exceeding the control group, which increased only from 40 to 45 (an increase of 5 points). The results of the Mann–Whitney U test showed Asymp. Sig. < .001 ($\alpha = 0.05$), confirming a significant difference in learning outcomes between the two groups. These findings demonstrate that Wordwall is effective in improving science learning outcomes holistically—cognitively, affectively, and psycho-motorically by providing a more engaging, interactive, and contextual learning experience.

Keywords: Cognitive learning outcomes; wordwall; discovery learning; digital science; ecosystem concept

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INTRODUCTION

Today's learners are digital natives who require new teaching styles to foster their motivation and engagement in academic learning. The current challenge is the implementation of alternative and modern teaching methods in the education curriculum, tailored to our cultural context. Digital game-based learning (DGBL) is one such method (Martinez et al., 2022). Game-based learning in elementary education has evolved, driven by technological advancements, educational research, and changes in pedagogical approaches. Digital game-based learning refers to using digital technologies, such as computers or mobile devices, to deliver educational content through interactive games (Behnamnia et al., 2023). These games often focus on literacy, numeracy, and early problem-solving. With the advent of computers and educational software, digital games emerged as a new medium for learning at the end of the 20th century (Alotaibi, 2024).

Educational systems worldwide have chosen to use DGBL as a way to assimilate technological innovation into education (Adetunji & Ade-Ibijola, 2024). Similarly, the Israeli education system and others around the world have initiated steps to integrate DGBL into school learning; however, in Israel, these steps are not part of a regulated policy, and the integration of DGBL into the educational framework appears to be progressing relatively slowly. Teachers describe the difficulties they face, as well as conceptual and professional barriers, that hinder their use of DGBL in learning. Digital games have emerged as a promising tool in educational environments, offering engaging and interactive experiences that enhance student motivation and learning outcomes. Research findings indicate that students who learn in a competitive mode significantly outperform those who do not in final tests (Zou et al., 2021). Competition is also an effective game element for encouraging students to learn actively and accept challenges. Liu et al. (2022) found that competitive games and personalized assistance enhance students' immersive experience and vocabulary learning efficiency but reduce their anxiety. Furthermore, DGBL is a beneficial method for achieving learning objectives, particularly in the cognitive domain (Ozdemir & Dinc, 2022).

In learning about ecosystems, the application of educational games based on games is considered important because through these games, concepts that are still difficult for students to understand, such as biogeochemical cycle material, can be studied more easily. The utilization of educational games as a learning medium is also expected to improve students' mastery of the material, as engaging learning activities make them more focused on observing and following the learning process (Rahmah & Risnani, 2023). Human activities are one of the causes of environmental damage on Earth. Prevention of environmental damage can be done by increasing ecological knowledge, problem-solving skills, and attitudes such as sustainability awareness and environmental awareness. One way to improve these competencies is by studying ecosystems and environmental changes.

Research results reveal that students who participate experience difficulties in constructing ecosystem concepts (Goodwin et al., 2019). For example, a study in the Philippines shows that understanding ecosystems is a core component of science education at the 8th-grade level, but many students struggle to understand complex interactions between organisms and their environment (Aydin & Kaya, 2016). The Department of Education in the Philippines has emphasized the need for innovative pedagogical strategies to improve conceptual learning in science. Although there has been rapid progress in educational technology and pedagogy, many schools, especially in developing countries, still rely heavily on traditional teaching methods (Garcia et al., 2025). The use of inconsistent concepts and poor understanding of argument elements often shown by prospective elementary school teachers is a problem that, according to Gámez et al. (2015), needs to be addressed at the ontological, epistemological, and conceptual levels.

Therefore, one of the learning strategies that can foster conceptual change and attitude towards these issues at all levels of education is necessary. In the context of learning, Eilam (2002) suggests using game-based learning combined with the discovery learning (DL) model so that students can practice their knowledge on a larger ecosystem scale while fostering interest and motivation during the learning process. The study results state that students prefer discovery-based learning if it is done outside the classroom because they can recognize abiotic and biotic components and observe interactions between biotic and abiotic components directly. In contrast, inside the classroom, they can only imagine these interactions without experiencing or seeing them directly. DL provides a perspective that can be used to analyze active student participation in constructing their knowledge. Additionally, the positive impact of DL on problem-solving competencies and independent learning (Weinhandl et al., 2025). Research findings from Martín-Gámez et al. (2020) show that students make progress in their understanding of key aspects related to ecosystem concepts. Specifically, they become more aware of the human role in the system, although they still experience difficulties in matters such as identifying species in aquatic ecosystems and distinguishing between biotic and abiotic components.

Responding to this urgency, the website-based Wordwall application can be used as an effective digital media intervention. Wordwall utilizes game-based learning principles that transform science material into interactive formats such as quiz shows, matching, or maze chases. Psychologically and pedagogically, this gamification functions as a trigger for intrinsic student motivation through instant feedback, leaderboards, and structured challenges, creating a competitive, enjoyable, and low anxiety learning environment. The use of Wordwall in science learning at the elementary school level has been proven to improve student learning achievement because it presents a more varied, creative, and interactive teaching method.

Research findings from Zaniyati and Rohmani (2024) show that the use of Word wall media significantly improves science learning outcomes and motivation and creates a more interactive and enjoyable learning atmosphere for students. The benefits of word wall include active student engagement, increased information retention, personalized learning, collaboration, and real-time feedback. Several studies have shown an increase in students' average scores after using Wardwell and an increase in student activeness and enthusiasm in participating in the learning process. Increased active student engagement through various Wordwall activities encourages the growth of learning motivation (Arsini et al., 2022), which ultimately positively impacts their academic performance. Research limitations on ecosystem concepts: Previous research has focused more on other scientific topics, while research on ecosystem concepts is still limited, especially at the elementary school level. Previous research has been mostly conducted at the secondary school or university level. Moreover, there is no research that specifically analyzes the effect of Wordwall on students' learning outcomes on ecosystem concepts. Previous research has focused on general science topics, so more specific research on ecosystem concepts is needed. Therefore, this study explores in-depth the use of Wordwall to improve science learning outcomes of elementary school students. In addition, Wordwall allows students to learn independently, which also strengthens the improvement of learning outcomes (Darmawati & Nayla, 2025).

Various studies also have confirmed that the use of interactive media in the learning process can significantly contribute to improving learning outcomes. Findings from Hamidah et al. (2023) show that Wordwall helps students understand and master concepts better and is flexibly used in both face-to-face and online learning. Research by Listiani (2024) reveals that this media encourages students to be more active, enthusiastic, and responsive during learning activities so that learning achievements become more optimal. Students show that they enjoy learning activities on Wordwall. Almost 90% of students state that they enjoy the learning. Ultimately, Wordwall is recommended for implementation in college classrooms. Furthermore, research by Bariyah (2024) states that Wordwall makes it easier for students to understand the material and helps determine the achievement of learning outcomes. Therefore, this study aims to find out the influence of the website-based Wordwall application media on students' science learning outcomes on ecosystem concepts.

METHODS

This study employed a quantitative approach with a quasi-experimental method. The specific design used was the non-equivalent control group design. Quasi-experimental designs must meet three primary requirements. First, there must be two groups: a group that receives treatment and a group that does not receive treatment. Second, measurements are necessary before and after the treatment is administered. Third, there must be a clear model to predict the differences between the treatment and non-treatment groups over time, without considering the impact of the treatment itself (Kenny, 1975) This design was selected to establish cause-and-effect relationships using pre-existing, non-randomized groups, which are commonly encountered in educational settings. The study involved two groups: Experimental Group and Control Group. The first group received science instruction using a website-based Wordwall application, integrated with the DL model. Meanwhile, control Group received conventional science instruction (lectures, question-and-answer sessions, and discussions), with identical materials, time allocations, and learning objectives as the experimental group.

This study was conducted at SD Negeri 15 Tual, with a population of all fifth-grade students. These students were spread across three classes in the fifth grade. To obtain a representative sample, the researcher used an appropriate sampling technique. The sample consisted of 31 students from Class 5c, who were designated as the experimental group, and 30 students from Class 5a, who served as the control group. The selection of Class 5c and Class 5a as samples was based on the consideration that both classes had comparable initial abilities. Thus, any differences in research outcomes could be attributed to the treatment provided, rather than differences in initial abilities. The sampling technique used in this study was a combination of purposive sampling and cluster sampling. Purposive sampling was used to select the classes that would serve as the experimental and control groups, based on the assumption of comparable initial abilities. Purposive sampling is a method commonly used in qualitative and mixed-methods research. The primary focus of this technique is to gain a detailed and contextual understanding. By selecting specific units, such as individuals, cases, or events, that are relevant to the research question, researchers can gain in-depth insights into complex phenomena (Tajik et al., 2024).

The research instrument used was a cognitive learning outcome test, consisting of levels C3-C5, to measure students' cognitive learning outcomes. The test instrument was in the form of 20 multiple-choice questions, which had been declared valid and reliable, as they met the instrument requirements. A pre-test was conducted before the treatment was given to determine students' initial abilities, while a post-test was conducted after the treatment was given to determine students' abilities after receiving the treatment. By using a valid and reliable test instrument, the researcher could obtain accurate data on students' cognitive learning outcomes before and after the treatment was given, allowing for an assessment of the effectiveness of the treatment.

Students who achieve an Excellent (87–100) score demonstrate full mastery of all learning objectives, can explain concepts clearly in their own words, and independently provide relevant and contextual examples without assistance. Students in the Good (73–86) category understand most of the learning objectives, can answer questions correctly, and explain concepts well, although they may occasionally require guiding questions or prompts from the teacher. Those in the Fair (60–72) range understand some of the concepts taught but still need guidance in providing explanations and examples, as their understanding is not yet consistent and requires further reinforcement. Meanwhile, students in the Needs Guidance (<60) category experience difficulties in understanding basic concepts and require additional support and remedial instruction to achieve the expected learning objectives. Quantitative analysis was performed using SPSS version 31. Instrument Testing consisted of validity was tested using Pearson Product Moment correlation. Reliability was measured using Cronbach's Alpha, with a threshold of ≥ 0.60. Prerequisite Testing was Normality test using Shapiro-Wilk (since $N < 50$). Homogeneity was tested using Levene's Test. For Hypothesis Testing, Since the data was normally distributed (Sig. ≥ 0.05) but not significantly homogeneous (Sig. Levene < 0.05), the non-parametric Mann-Whitney U Test was chosen (Nachar, 2008). The alternative hypothesis (H_α) was accepted if Asymp. Sig. < 0.05.

RESULTS & DISCUSSION

Results

The main topic of the lesson is Ecosystem, which covers several learning materials supported by Word-Wall activities. Students will learn about identifying biotic and abiotic components (https://bit.ly/MeetingA01), exploring types of living organism interactions and their examples (https://bit.ly/MeetingA02), classifying living organisms into producer, consumer, and decomposer roles in coastal ecosystems (https://bit.ly/MeetingA03), and matching living organism relationships in the form of food chains and food webs (https://bit.ly/MeetingA04). Instrument testing ensures the quality of the measuring tool. Validity testing shows that all 20 items have r_{count} value greater than the critical r_{table} (0.456), so all items are declared valid. Reliability testing produces a Cronbach's Alpha of 0.973. This value indicates high internal consistency and reliability, guaranteeing the instrument's ability to measure learning outcomes accurately and consistently.

Table 1. Comparison of Average Pretest and Posttest Scores

Group	Average Pretest	Average Posttest	Increase	SD Posttest
Experiment	30	85	55	6.30 (Low)
Control	40	45	5	(High)

The descriptive results show a sharp contrast in which the average score of the experimental group increased by 55 points, far surpassing the control group, which only increased by 5 points. The final average score of the experimental group (85) placed most students in the "Good" to "Very Good" category, while the control group (45) remained in the "Needs Guidance" category. Prerequisite testing showed that the posttest data were normally distributed in both groups (Sig. Shapiro-Wilk = 0.080 for both; > 0.05). However, the Homogeneity Test (Levene's Test) produced a Sig. value < 0.001. Since this value < 0.05, the assumption of homogeneity of variance was significantly violated. Therefore, the Mann-Whitney U Test was used to compare differences in median ranks.

Tabel 2. Results of the Mann-Whitney U Hypothesis Test

Statistical Test	Asymp. Sig. (2-tailed)	Decision	Conclusion
Mann-Whitney U	< 0.001	H_0 rejected (Sig. < 0.05)	There is a significant difference

The discussion of the research findings focuses on the interpretation of statistical results and analysis of the pedagogical mechanisms underlying the effectiveness of the Wordwall application media. The results of the Mann-Whitney U Test, which showed an Asymp. Sig. value < 0.001 (far below the tolerance limit $\alpha = 0.05$), provide strong statistical evidence to reject the Null Hypothesis (H_0) and accept the Alternative Hypothesis (H_α). This decision definitively confirms that there is a statistically significant difference between the learning outcomes of science students in the experimental group using Wordwall and the control group using conventional methods.

Statistical Validation of Gains and Analysis of Intervention Effectiveness

This significant difference translates into a dramatic increase in scores. The experimental group experienced an average increase of 55 points (from pretest 30 to posttest 85), an extraordinary leap, while the control group only increased by 5 points (from pretest 40 to posttest 45). This achievement is consistent with the literature supporting the use of gamification and interactive digital media in science learning in elementary schools. The formal data from the hypothesis test are presented below, including the Mann-Whitney U Hypothesis Test from the SPSS output:

Table 3. Results of the Mann-Whitney U Hypothesis Test

Test Statistics [a]	
	Science Learning Outcomes
Mann-Whitney U	14.000
Wilcoxon W	479.000
Z	-6.546
Asymp. Sig. (2-tailed)	< 0.001
a. Grouping Variable: Group	

The results of the Mann-Whitney U hypothesis test yielded an Asymp. Sig. (2-tailed) value of <.001. The comparison obtained is: Asymp. Sig. value (<.001) < α (0.05). Since the Asymp. Sig. value is less than 0.05, the Null Hypothesis (H_0) is rejected. This rejection of H_0 simultaneously proves the acceptance of the Alternative Hypothesis (Hα). The rejection of H_0 and acceptance of Hα imply that there is a significant difference in the science learning outcomes of students between the group that received treatment using the website-based Wordwall media and the group that used conventional learning methods.

Table 4. Comparison of Average Learning Outcomes on the Ecosystem Concept

Group	Pretest	Posttest
Experiment	45	85
Control	35	55

Specifically, the posttest results confirm the failure of the control group to achieve the minimum standard set by the curriculum. The average posttest score of the experimental group (85) falls within the "Good" category and successfully exceeds the Criteria for Achieving Learning Objectives (KKTP), which is 60. In contrast, the average score of the control group (45) remains in the "Needs Guidance" category, indicating that the majority of students in this group do not meet the basic competencies of the subject. The quality of achievement is evidenced by the high consistency of results. The average posttest score of the experimental group (85) has a very low Standard Deviation (6.30). This low Standard Deviation indicates that the learning outcomes of students become more uniform and even after the Wordwall intervention, proving that this media can provide an equitable learning experience for all students, regardless of their initial abilities. In contrast, the control group likely has a much larger Standard Deviation, indicating a sharp variation in understanding. In the control group, the minimum value recorded is 30, the first quartile (Q1) is 35, the median or middle value is 45, the third quartile (Q3) is 55, and the maximum value reaches 80. This shows that most students in the control group have scores below 60, with a relatively wide data distribution (30-80). The wide range indicates that the abilities of students in the control group vary greatly, with most still being in the low to moderate category.

Meanwhile, in the experimental group, the learning outcomes show a significant increase. The minimum value is 70, the first quartile is 80, the median is 82.74, the third quartile ranges from 85-90, and the maximum value reaches 95. This shows that majority of students in the experimental group obtain high scores, with a narrower data distribution (70-95). The narrow range indicates that the learning outcomes of students in the experimental group are more consistent and tend to be evenly distributed at a high level. When compared between the two groups, the median of the experimental group (≈83) is much higher than the median of the control group (45). This difference in median indicates a significant increase in learning outcomes after the application of the Wordwall-based learning media in the experimental group. Furthermore, the position and size of the box in the diagram also show that the distribution of values in the experimental group is more homogeneous, indicating that the Wordwall media can help students understand the material more evenly. The visualization of Diagram 2 clearly shows that the Experimental Group (Wordwall) has a very short range and is centered on a high value (around 85). This is strong visual evidence that the dispersion of scores is very narrow (Standard Deviation 6.30), confirming the consistency of learning. In contrast, the control group shows a long box, indicating a wide distribution of data and uneven learning outcomes. This visualization also confirms the methodological decision to use the Mann-Whitney U Test, as it explicitly shows the heterogeneity of variance between groups.

Discussion

This study aims to investigate the extent to which digital game media based on word-wall with the DL model can provide benefits in improving the cognitive learning outcomes of 5th-grade students at SD Negeri 15 Tual on ecosystem material. The results of the study show that the application of digital game media can encourage an increase in students' cognitive learning of science. This indicates that digital game media based on word-wall with the DL model can be an effective learning tool in improving students' cognitive learning outcomes. By using digital game media, students can interact directly with learning materials, thereby increasing their understanding and mastery of the material. Additionally, digital game media can make learning more engaging and enjoyable, so students can be more motivated to learn. The application of digital game media based on word-wall with the DL model can also help students understand complex concepts in ecosystem material. Students can utilize digital game media to improve their understanding and mastery of the material, thereby increasing their cognitive learning outcomes. Digital game media can present learning materials in a more interactive and engaging way, making it easier for students to understand complex concepts. Furthermore, digital game media can help students develop critical and creative thinking skills, thereby improving their cognitive learning outcomes.

The results of this study also show that digital game media can be an alternative to improving students' cognitive learning outcomes. Therefore, teachers can consider using digital game media in the learning process. Digital game media can be an effective learning tool in improving students' cognitive learning outcomes, especially in complex materials like ecosystems. Additionally, digital game media can help teachers increase learning efficiency, thereby improving students' cognitive learning outcomes. However, it is essential to note that this study has limitations, such as a limited sample size and short research duration. Therefore, further research is needed to measure the long-term impact of using digital game media based on Wordwall with the DL model. Further research can help understand more about the effectiveness of digital game media in improving students' cognitive learning outcomes and identify factors that influence the success of using digital game media in learning.

These findings are in line with previous studies that state that digital games have a positive impact on learning motivation. Digital games have been proven to strengthen cognitive abilities, including problem-solving skills, memory, intention, and spatial abilities (Ramli et al., 2020). This fact is a foundation for researchers to continue developing digital game-based learning models due to their practical and engaging nature. Additionally, various previous studies have also developed similar approaches. Learning that utilizes digital games as media has a positive impact on students' learning motivation (Li et al., 2024). In general, the use of digital games can increase the efficiency and effectiveness of the learning process. Furthermore, previous studies have also shown that digital games can improve students' cognitive abilities, including critical, creative, and analytical thinking skills. Digital games can also help students develop social skills, such as cooperation, communication, and empathy. Additionally, digital games can increase students' learning motivation, as students can experience enjoyment and challenge in the learning process. In the context of education, digital games can be an effective learning tool, as they can increase student engagement in the learning process. Digital games can also help teachers increase learning efficiency, as they can reduce the teacher's workload in delivering learning materials. Furthermore, digital games can help students develop 21st-century skills, such as critical, creative, and analytical thinking skills.

Another study by Alfares (2025) found that the use of Wordwall enhances learners' vocabulary acquisition and increases achievement levels. Students in the experimental group achieved a higher level in the post-test vocabulary compared to those in the control group. Moreover, the experimental group obtained higher scores in the post-test vocabulary. The research findings showed a significant positive outcome in the group that used Wordwall, confirming its effectiveness as a learning medium. The results of this study differ from those of a study conducted by (Han et al. (2025), which found that Wordwall did not have a significant impact on vocabulary learning in an EFL context. However, the findings of this study align with those of a study conducted on elementary school students, which reported a significant increase in both the experimental and control groups, with a more pronounced performance in the experimental group. Various previous studies that assessed teachers' and students' perceptions of Wordwall also confirmed its benefits and positive attitudes towards its use. This study provides additional support for those findings. According to Zhang and Yu (2021), gamification platforms such as Quizizz, Kahoot, and Wordwall stimulate engagement, collaboration, discussion, and negotiation of meaning among students. The integration of several learning technologies is considered to better meet learning needs, improve student competence, strengthen critical thinking and problem-solving skills, and facilitate participation and collaboration. All these processes help students develop their cognitive skills in science.

The concept of DL began to develop in the 1960s, when Jerome Bruner was one of the first to explain in detail the benefits of an instructional approach that focuses on discovery learning (Bruner, 1961). Since then, various learning design approaches that incorporate elements of DL have been developed, such as exploratory learning, inquiry-based learning, and problem-based learning (Kuhn et al., 2000). DL and related learning design approaches are supported by cognitive constructivist theory, which is rooted in Piaget's idea of active knowledge construction through exploration and interaction with the environment (Klahr & Nigam, 2004). Furthermore, the study by Dalgarno et al. (2014) opens up new insights into the importance of active exploration in DL. These findings suggest that although the limitations of learners' ability to manipulate simulations can provide valuable structure, with proper guidance during the exploration process, active exploration can lead to better learning outcomes than simply observing simulation results passively. Therefore, Wordwall can be an effective tool in supporting discovery learning, allowing learners to actively explore and discover new concepts in a fun and interactive way.

In the context of project-based learning, Wordwall helps students understand concepts of ecosystems, climate change, and environmental sustainability through educational games, quizzes, and interactive activities. This approach makes learning more engaging, easy to understand, and tailored to the students' developmental stage. By interacting directly with Wordwall, students not only receive information but also actively think critically, collaborate, and reflect on the impact of human behavior on the environment. Additionally, Wordwall supports the goals of P5 in strengthening the character of Pancasila Student Profile, such as critical reasoning, mutual assistance, and moral behavior towards nature. When students learn about ecosystems through digital media that is close to their daily lives, learning becomes more meaningful and encourages ecological awareness.

Thus, Wordwall serves as a bridge between P5 studies, ecosystem issues, and innovative learning that fosters environmental sensitivity from an early age. Therefore, the implementation of this project has a crucial role in building a conducive learning atmosphere and supporting the overall development of students. P5 is expected to be an evaluation instrument to determine priority themes that align with the needs of students. Through this, the implementation of P5 can run more effectively in encouraging students to become lifelong learners who are competent, have strong character, and behave in line with Pancasila values. The use of surveys also provides space for students to feel more involved in the learning process and view themselves as active parties in the behavioral changes they experience. This increased involvement has the potential to strengthen students' learning motivation and foster a deeper commitment to forming the Pancasila Student Profile.

Engaging in systemic reasoning related to ecological issues is a crucial aspect of learning for early elementary school students. This is because systemic reasoning can help students understand critical environmental issues, such as global warming and biodiversity decline, that they will face in the future. Unfortunately, ecological issues are often not taught using an approach that highlights systemic reasoning at the elementary school level. As a result, students may not gain a deep understanding of the interconnectedness between components in ecological systems and their impact on the environment. Through systemic reasoning, students can comprehend how components in ecological systems interact and influence each other, enabling them to develop more holistic and integrative thinking in addressing environmental issues. Therefore, teaching systemic reasoning about ecological issues in early elementary school can provide a strong foundation for students to become environmentally conscious and sustainable citizens in the future (Hokayem & Gotwals, 2016).

Students' understanding of ecosystems is a crucial aspect of sustainable environmental management. By grasping the concept of ecosystems, students can comprehend how components within an ecosystem interact and influence one another, enabling them to develop a more holistic and integrative thinking approach to addressing environmental issues. This understanding also allows students to appreciate the importance of sustainable utilization, conservation, and development of ecosystems. Through learning about ecosystems, students can equip themselves with knowledge and information on maintaining ecosystem balance, both currently and in the future. They can understand how human activities impact ecosystems and how they can contribute to preserving ecosystem balance. Consequently, students can develop environmental awareness and responsibility, as well as appreciate the significance of sustainable environmental management (Gal et al., 2021). In this context, Wordwall can be an effective tool for enhancing students' understanding of ecosystems. By utilizing Wordwall, students can engage with ecosystem-related learning materials in a more engaging and interactive manner. They can play games, answer questions, and participate in other activities that can help them better comprehend ecosystem concepts.

CONCLUSION

Based on the research findings obtained, the use of the website-based Wordwall application is highly recommended as a primary strategy in science learning for fifth-grade elementary school students. This recommendation is supported by the results of statistical analysis using the Mann-Whitney U test, which shows an Asymp. Sig. value of < 0.001 at a significance level of $\alpha = 0.05$. The results clearly confirm the existence of a significant difference in learning outcomes between the group using Wordwall and the conventional learning group, allowing us to conclude that the implementation of Wordwall has a positive impact on improving student learning outcomes. Therefore, teachers are encouraged to integrate the use of Wordwall regularly and systematically in the learning process, especially for abstract materials that are difficult to understand when presented through lectures only. This platform has proven to be able to help students understand concepts more concretely through attractive visualizations, game-based activities, and immediate feedback. In addition, the use of Wordwall should be combined with the DL model so that students not only gain theoretical conceptual understanding but also can apply these concepts contextually in daily life through independent discovery and exploration. On the other hand, the school plays an important role in supporting the success of this implementation, namely by providing training for teachers to optimize all Wordwall features that support visualization, gamification, and formative assessment. With adequate training, teachers can design more interactive, innovative, and student-centered learning. Consistent implementation of Wordwall is believed to increase student learning motivation, reduce cognitive load, and strengthen the affective and psychomotor aspects of students in science learning, so that learning objectives can be achieved more optimally and sustainably.

REFERENCES

Adetunji, R. O., & Ade-Ibijola, A. (2024). Unlocking learning: investigating the replayability of educational games. *International Journal of Computer Games Technology*, *2024*, 1–14. https://doi.org/10.1155/2024/5876780

Alfares, N. S. (2025). Investigating the efficacy of wordwall platform in enhancing vocabulary learning in Saudi EFL classroom. *International Journal of Game-Based Learning*, *15*(1), 1–12. https://doi.org/10.4018/IJGBL.367870

Alotaibi, M. S. (2024). Game-based learning in early childhood education: a systematic review and meta-analysis. *Frontiers in Psychology*, *15*, 1–11. https://doi.org/10.3389/fpsyg.2024.1307881

Arsini, N. N., Santosa, M. H., & Marsakawati, N. P. E. (2022). Hospitality school students' perception on the use of wordwall to enrich students' work-ready vocabulary mastery. *Elsya : Journal of English Language Studies*, *4*(2), 124–130. https://doi.org/10.31849/elsya.v4i2.8732

Aydin, B., & Kaya, A. (2016). Sources of stress for teachers working in private elementary schools and methods of coping with stress. *Universal Journal of Educational Research*, *4*(12A), 186–195. https://doi.org/10.13189/ujer.2016.041324

Bariyah, C. (2024). Application of word wall to foster students' understanding of science learning. *Sustainable Jurnal Kajian Mutu Pendidikan*, *7*(1), 88–97. https://doi.org/10.32923/kjmp.v7i1.4467

Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, S. A. (2023). A review of using digital game-based learning for preschoolers. In *Journal of Computers in Education* (Vol. 10, Issue 4). Springer Berlin Heidelberg. https://doi.org/10.1007/s40692-022-00240-0

Bruner, J. S. (1961). The act of discovery. In *In Search of Pedagogy Volume I* (pp. 21–32). https://doi.org/10.4324/9780203088609-13

Dalgarno, B., Kennedy, G., & Bennett, S. (2014). The impact of students' exploration strategies on discovery learning using computer-based simulations. *Educational Media International*, *51*(4), 310–329. https://doi.org/10.1080/09523987.2014.977009

Darmawati, & Nayla. (2025). The effect of using wordwall website as a strategy on students' vocabulary mastery. *International Journal of Educational Research*, *2*(2), 64–70. https://doi.org/10.62951/ijer.v2i2.311

Gal, A., Gan, D., & Ben-Zvi Assaraf, O. (2021). The use of the lesser kestrel ' s life cycle to enhance elementary school children ' s understanding of complex systems. *Interdisciplinary Journal of Environmental and Science Education*, *17*(1), 1–19.

Gámez, C. M., Ruz, T. P., & López, Á. J. (2015). Trends of pre-service science teachers about the methodological strategies in science teaching. Case study in Málaga. *Ensenanza de Las Ciencias*, *33*(1), 167–184. https://doi.org/10.5565/rev/ensciencias.1500

Garcia, M. P., Domingo, A. C., Lagansua, R. M., & Matalandang, S. M. T. (2025). Enhancing grade 8 students' understanding of ecosystems through technology-enhanced active learning (TEAL). *Asian Journal of Education and Social Studies*, *51*(8), 31–37. https://doi.org/10.9734/ajess/2025/v51i82219

Goodwin, S., Brogaard, S., & Krause, T. (2019). Values held by Swedish primary school students towards forest ecosystems and the relevance for a nature's contributions to people approach. *Ecosystems and People*, *15*(1), 331–346. https://doi.org/10.1080/26395916.2019.1687585

Hamidah, F., Setiawan, F., & Mirnawati, L. B. (2023). Strenghthening digital literacy of elementary school students through utilization of wordwall as game-based learning interactive media. *Jurnal Ilmiah Sekolah Dasar*, *7*(2), 215–223. https://doi.org/10.23887/jisd.v7i2.55807

Han, L. T., Thi, P., & Huyen, T. (2025). Impacts of wordwall online games on vocabulary retention and attitudes among EFL high school learners. *RA Journal Of Applied Research*, *11*(11), 1065–1072. https://doi.org/10.47191/rajar/v11i11.14

Hokayem, H., & Gotwals, A. W. (2016). Early elementary students ' understanding of complex ecosystems : a learning progression approach. *Journal of Research in Science Teaching*, *53*(10), 1–22. https://doi.org/10.1002/tea.21336

Kenny, D. A. (1975). A quasi-experimental approach to assessing treatment effects in the nonequivalent control group design. *Psychological Bulletin*, *82*(3), 345–362. https://doi.org/10.1037/0033-2909.82.3.345

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. *Psychological Science*, *15*(10), 661–667. https://doi.org/10.1111/j.0956-7976.2004.00737.x

Kuhn, D., Black, J., Keselman, A., & Kaplan, D. (2000). The development of cognitive skills to support inquiry learning. *Cognition and Instruction*, *18*(4), 495–523. https://doi.org/10.1207/S1532690XCI1804_3

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), 1–21. https://doi.org/10.1371/journal.pone.0294350

Listiani, T. (2024). Implementing wordwall in teaching sampling techniques for higher education students. *KnE Social Sciences*, *2024*, 458–467. https://doi.org/10.18502/kss.v9i8.15582

Liu, Y. J., Zhou, Y. G., Li, Q. L., & Ye, X. D. (2022). Impact study of the learning effects and motivation of competitive modes in gamified learning. *Sustainability (Switzerland)*, *14*(11), 1–14. https://doi.org/10.3390/su14116626

Martín-Gámez, C., Acebal, M. del C., & Prieto, T. (2020). Developing the concept of 'ecosystem' through inquiry-based learning: a study of pre-service primary teachers. *Journal of Biological Education*, *54*(2), 147–161. https://doi.org/10.1080/00219266.2018.1554596

Martinez, L., Gimenes, M., & Lambert, E. (2022). Entertainment video games for academic learning: a systematic review. *Journal of Educational Computing Research*, *60*(5), 1083–1109. https://doi.org/10.1177/07356331211053848

Nachar, N. (2008). The mann-whitney u: a test for assessing whether two independent samples come from the same distribution. *Tutorials in Quantitative Methods for Psychology*, *4*(1), 13–20. https://doi.org/10.20982/tqmp.04.1.p013

Ozdemir, E. K., & Dinc, L. (2022). Game-based learning in undergraduate nursing education: A systematic review of mixed-method studies. *Nurse Education in Practice*, *62*, 1–10. https://doi.org/10.1016/j.nepr.2022.103375

Rahmah, S., & Risnani, L. Y. (2023). Development of educational game-based learning media to improve mastery of ecosystem material in high school students. *Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan*, *2*(2), 84–98. https://doi.org/10.58362/hafecspost.v2i2.42

Ramli, I. S. M., Maat, S. M., & Khalid, F. (2020). Game-based learning and student motivation in mathematics. *International Journal of Academic Research in Progressive Education and Development*, *9*(2), 449–455. https://doi.org/10.6007/ijarped/v9-i2/7487

Tajik, O., Golzar, J., & Noor, S. (2024). Purposive Sampling. *International Journal of Education & Language Studies*, *2*(2), 1–9. https://doi.org/10.4135/9781412963909.n349

Weinhandl, R., Baldinger, S., & Riegler, V. (2025). Design characteristics for discovery learning within digital mathematics learning environments from students' perspectives. *International Journal of Science and Mathematics Education*, 1–29. https://doi.org/10.1007/s10763-025-10619-x

Zaniyati, M., & Rohmani, R. (2024). Analysis of the effectiveness of pop-up book media on science learning in elementary schools. *IJORER : International Journal of Recent Educational Research*, *5*(4), 919–934. https://doi.org/10.46245/ijorer.v5i4.641

Zhang, Q., & Yu, Z. (2021). A literature review on the influence of Kahoot ! On learning outcomes , interaction , and collaboration. *Education and Information Technologies*, *26*, 4507–4535.

Zou, D., Zhang, R., Xie, H., & Wang, F. L. (2021). Digital game-based learning of information literacy: Effects of gameplay modes on university students' learning performance, motivation, self-efficacy and flow experiences. *Australasian Journal of Educational Technology*, *37*(2), 152–170. https://doi.org/10.14742/AJET.6682