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Effects of PQ4R-Based Microlearning on Scientific Literacy and Biology Achievement: A Quasi-Experimental Study Controlling Prior Knowledge

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Abstract: This study aims to analyze the effect of implementing the PQ4R learning model assisted by video microlearning on students' scientific literacy and biology learning outcomes in the nervous system material. The study used a quantitative approach with a quasi-experimental nonequivalent control group design. The experimental class was taught using the PQ4R model assisted by video microlearning, while the control class used Project Based Learning (PjBL). Video microlearning was integrated in the Read and Reflect stages to help visualize abstract nervous system concepts. The study sample consisted of 36 students in the experimental class and 35 students in the control class. Data were analyzed using descriptive statistics and analysis of covariance (ANCOVA). The results showed that the average posttest of scientific literacy in the experimental class was 92.44, higher than the control class at 87.20. The average posttest of biology learning outcomes in the experimental class was 93.33, while the control class was 87.89. ANCOVA results showed that the learning model had a significant effect on scientific literacy ($F = 29.282$; $p < 0.001$; $\eta^2 = 0.301$) and biology learning outcomes ($F = 26.082$; $p < 0.001$; $\eta^2 = 0.277$) after initial abilities were controlled. The research findings showed that the PQ4R model assisted by microlearning videos was more effective than Project Based Learning (PjBL) in helping students understand the concept of the nervous system and improving scientific literacy and biology learning outcomes.

Keywords: ANCOVA; Biology Learning Outcomes; Microlearning; PQ4R; Scientific Literacy

Introduction

Scientific literacy is a crucial competency for 21st-century students, as it encompasses the ability to understand scientific concepts, analyze phenomena, evaluate evidence-based information, and make rational decisions in everyday life (Elhai, 2023). These skills serve as the foundation for students to address various global issues, such as climate change, technological developments, health issues, and increasingly complex environmental problems (Eilam, 2022). Scientific literacy emphasizes not only conceptual mastery but also the ability to use scientific knowledge to explain phenomena, solve contextual problems, and interpret information critically and reflectively (Bramastia & Rahayu, 2023; Elhai, 2023).

The importance of scientific literacy has not been fully reflected in optimal student achievement (Osborne, 2023; Valladares, 2021). The 2022 Programme for International Student Assessment (PISA) results show that Indonesian students' scientific literacy scores remain below the OECD average (Ivanka & Setiawan, 2025; Nurvidian et al., 2025). This low achievement indicates that most students still experience difficulties in understanding scientific concepts, interpreting data, and connecting scientific knowledge to real-world situations (Trisanti et al., 2025). This situation indicates that the learning process still needs to be directed at

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developing conceptual understanding and higher-order thinking skills, rather than simply memorizing material (Miedijensky et al., 2021).

Low scientific literacy skills are often related to learning processes that don't fully provide space for students to actively construct knowledge (Kerkhoff & Makubuya, 2022; Nurvidian et al., 2025). Learning activities that still focus on conveying information result in students receiving more material than exploring, questioning, and reflecting on the concepts they are learning (Hasanah et al., 2023). This situation results in low student engagement in the learning process, resulting in a less in-depth understanding of concepts that are easily forgotten (Kallia & Sentance, 2021).

This problem is also found in biology learning, which is characterized by conceptual, contextual, and partly abstract material (Amin et al., 2022; Henningsen-Schomers & Pulvermüller, 2022). Learning biology requires students not only to memorize terms and structures but also to systematically understand the interrelationships between life processes (Momsen et al., 2022). A sound understanding of biological concepts is necessary for students to be able to explain biological phenomena scientifically and relate them to everyday life (Luft et al., 2022).

One biology topic often considered difficult by students is the nervous system. This topic encompasses abstract concepts, such as impulse transmission mechanisms, neuron coordination, and the complex and dynamic relationships between nerve organ (Kvello & Gericke, 2021). These biological processes are difficult to observe directly, so students often struggle to visualize the flow and interrelationships between concepts (Strømme & Mork, 2021). As a result, learning tends to stagnate into memorization without fully understanding biological processes.

Difficulty understanding nervous system material can impact student learning outcomes. Learning outcomes are an important indicator in assessing the success of the learning process because they demonstrate the extent to which students are able to understand and master the material being studied (Schlatter et al., 2022). Low learning outcomes indicate that students have not yet achieved optimal conceptual understanding. This situation demonstrates that improving learning outcomes cannot be separated from efforts to strengthen students' scientific literacy.

Strengthening scientific literacy and learning outcomes requires a learning process that actively engages students in constructing knowledge (Nuraini et al., 2023). Students need to be given the opportunity to explore information, formulate questions, connect concepts, and reflect on the understanding gained during the learning process (Hansen, 2023). Learning models that provide space for these thinking activities are considered more capable of helping students understand concepts in depth and meaningfully (Kamila et al., 2024).

Initial observations of biology instruction at SMA Negeri 13 Bone indicate that learning activities are still dominated by note-taking and completing assignments. Students tend to passively receive information, thus limiting opportunities for discussion, developing questions, and building conceptual understanding. The use of learning media also does not fully facilitate the visualization of abstract biology concepts, particularly those related to the nervous system. This situation causes some students to struggle to fully understand biological processes.

One learning model that has the potential to help address these issues is the PQ4R (Preview, Question, Read, Reflect, Recite, Review) model. The PQ4R model is a learning strategy that emphasizes active student involvement through systematic learning stages (Sohail & Iqbal, 2025). Each stage in the PQ4R model is designed to help students gradually understand the material, from gaining an initial overview to reviewing previously learned concepts (Sartika & Hadi, 2021).

The preview stage helps students gain an initial orientation to the material while activating prior knowledge. The question stage encourages students to formulate critical questions that can improve learning focus (Insuasty Cárdenas, 2020). The read and reflect stage helps students understand and connect new information with prior knowledge (Teng, 2020). The recite and review stage strengthens understanding through active repetition and a thorough review of the material. These characteristics indicate that the PQ4R model has the potential to improve conceptual understanding, scientific literacy, and student learning outcomes (Hasibuan et al., 2024; Selfianti et al., 2022).

However, the application of the PQ4R model in various previous studies has generally focused on conventional text-based reading strategies. PQ4R use is more directed at reading comprehension activities through books or written materials (Hasanah et al., 2023). However, developments in educational technology show that today's students are more familiar with visual and digital learning resources than with long, monotonous texts (Dahlström, 2022). This situation indicates the need to develop the PQ4R model to be more relevant to the characteristics of learning in the digital era.

This research presents a novelty through the integration of the PQ4R model with microlearning videos. This integration makes PQ4R not only function as a text literacy strategy, but also develop into a multimedia-based learning strategy that supports students' digital literacy. Unlike previous research that tends to use PQ4R as a conventional text-based reading strategy, this study develops PQ4R into a multimedia-based learning strategy through the integration of microlearning videos at certain learning stages. This integration not only supports conceptual understanding but also strengthens students' engagement in a more interactive and contextual digital learning process.

Microlearning videos are short, video-based learning media designed to convey a single concept in a specific and focused manner (Abidin, 2025). The concise, visual, and to-the-point presentation of the material helps students grasp complex concepts more easily (Hasanah et al., 2023; Ristana, 2022). This short learning format is also considered more appropriate for the characteristics of learners in the digital age, who tend to have shorter attention spans when absorbing learning information (Lodge & Harrison, 2019).

Microlearning videos are considered suitable for the nervous system because they can visualize biological processes that are difficult to observe directly (Boumalek et al., 2025). The mechanisms of nerve impulse transmission, the connections between neurons, and the coordination of nervous system function can be displayed through animation and dynamic visualization, helping students understand the process flow more clearly (Taylor & Hung, 2022). This visual presentation helps reduce the tendency for students to simply memorize concepts without understanding the interrelationships between biological processes (Jamaludin, 2023).

The integration of microlearning videos in the PQ4R model is carried out at several learning stages, particularly the preview, read, and reflect stages. Microlearning videos are used in the preview stage to provide an initial overview of nervous system concepts so that students gain a learning orientation before delving deeper into the material (Giurgiu, 2017; Mahardika et al., 2024). In the read and reflect stages, microlearning videos are used to help students understand, connect, and reflect on biological processes through more concrete visualizations. Thus, videos not only function as supporting learning media but also become part of the learning stages in the PQ4R model (Alshammari, 2024; Hlazunova et al., 2024; Zhang & West, 2020). This integration is expected to create a more interactive, adaptive, and meaningful learning process.

The use of microlearning videos also aligns with developments in educational technology, which emphasize flexibility and active student involvement in the learning process. Students can access materials independently, repeat videos as needed, and learn concepts incrementally. This allows for a more flexible learning process tailored to each student's individual learning characteristics (Alias & Razak, 2025; Monib et al., 2025).

The application of the PQ4R model, supported by video microlearning, also supports the implementation of the Independent Curriculum, which emphasizes competency-based learning, differentiation, and character building (Abidin, 2025). Learning that encourages students to think critically, actively explore information, and deeply understand concepts is considered aligned with the learning objectives of the Independent Curriculum.

Students' prior abilities are a crucial factor in implementing the PQ4R model because the preview stage activates prior knowledge (Lodge & Harrison, 2019). Students with varying prior abilities may have varying levels of understanding when receiving new information. These differences can impact the effectiveness of the applied learning model, so prior abilities need to be controlled for to ensure the research results truly demonstrate the effects of the treatment.

Initial ability control in this study was conducted using analysis of covariance (ANCOVA). The purpose of ANCOVA was to control for the influence of students' initial abilities so that the analysis of the effect of the PQ4R model assisted by video microlearning on scientific literacy and learning outcomes could be conducted more accurately. This control is important to ensure that improvements in learning outcomes and scientific literacy truly stem from the implementation of the learning model used.

Research on the integration of the PQ4R model and microlearning videos in biology learning is still relatively limited. Most previous studies examined the PQ4R model and microlearning media separately, resulting in limited research explaining how their integration can simultaneously support improved scientific literacy and learning outcomes. Furthermore, research integrating the PQ4R model and microlearning videos on the nervous system at the high school level is also very limited, particularly research that simultaneously examines their effects on scientific literacy and learning outcomes by controlling for students' initial abilities using ANCOVA.

Based on the above description, research on the effect of implementing the PQ4R model assisted by video microlearning on scientific literacy and student learning outcomes in the nervous system material at SMA Negeri 13 Bone is important to conduct. This research is expected to contribute to the development of Biology learning strategies that are more relevant to the characteristics of students in the digital era while simultaneously supporting the improvement of scientific literacy and learning outcomes more optimally. Therefore, this research is important to conduct as an effort to present Biology learning innovations that not only improve learning outcomes, but also strengthen students' scientific literacy through learning that is adaptive to the development of 21st-century educational technology (Ayani et al., 2025).

Method

This study employed a quantitative approach with a quasi-experimental design using a Pretest–Posttest Nonequivalent Control Group Design. The study was conducted in the even semester of the 2025/2026 academic year at SMA Negeri 13 Bone. The study population consisted of all 209 eleventh-grade students, spread across six classes. The sample was determined using cluster random sampling because the research unit was a pre-formed, intact class. The drawing determined that class XI A2, consisting of 36 students, served as the experimental class, and class XI A1, consisting of 35 students, served as the control class.

The study design involved two groups: the experimental class and the control class. Both groups were given a pretest to determine students' initial abilities before the treatment was administered. The experimental class received instruction using the PQ4R model assisted by microlearning videos, while the control class used the Project-Based Learning (PjBL) model. PjBL was selected as the control group based on its characteristics as an active learning model widely implemented in the Independent Curriculum and its student-centered learning orientation. The use of PjBL as a comparison group aims to test the effectiveness of the PQ4R model assisted by video microlearning compared to other active learning models in improving students' scientific literacy and biology learning outcomes. After all treatments were completed, both groups were given a posttest to measure changes in student abilities after the learning process. The research was conducted over six sessions, including one pretest, four treatment sessions, and one posttest. Treatments were administered according to the learning syntax for each research group.

The PQ4R model is implemented through six learning stages: preview, question, read, reflect, recite, and review. Microlearning videos are integrated into the preview, read, and reflect stages to help students visualize abstract concepts in the human nervous system, particularly the mechanisms of nerve impulse transmission, interneuron connections, and nervous system coordination. The use of microlearning videos at these stages aims to help students understand the relationships between concepts more concretely and deeply.

The research instruments consisted of a scientific literacy test and a biology learning outcome test. The scientific literacy instrument was adapted and modified from the Test of Scientific Literacy Skills (TOSLS) developed by Gormally et al. (2012). The instrument consisted of 25 multiple-choice questions tailored to the characteristics of the human nervous system and the research objectives. Scientific literacy indicators include the ability to explain scientific phenomena, evaluate and design scientific investigations, and interpret scientific data and evidence.

The biology learning outcome test consisted of 25 multiple-choice questions that measured cognitive abilities at levels C1 to C5, including remembering, understanding, applying, analyzing, and evaluating biological concepts. All research instruments were validated by expert lecturers through expert judgment.

Data collection was conducted through pretests and posttests in both research groups. The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to describe the mean score, standard deviation, minimum score, and maximum score for the research variables. Inferential analysis was conducted using Analysis of Covariance (ANCOVA) with pretest scores as a covariate to control for students' initial abilities.

Before hypothesis testing, the data were first tested using the Shapiro–Wilk normality test, Levene's homogeneity of variance test, and homogeneity of regression slopes test to ensure there was no interaction between the covariates and the independent variables. Hypothesis testing was conducted at a significance level of 0.05 using IBM SPSS Statistics version 27. The research flow can be seen in Figure 1.

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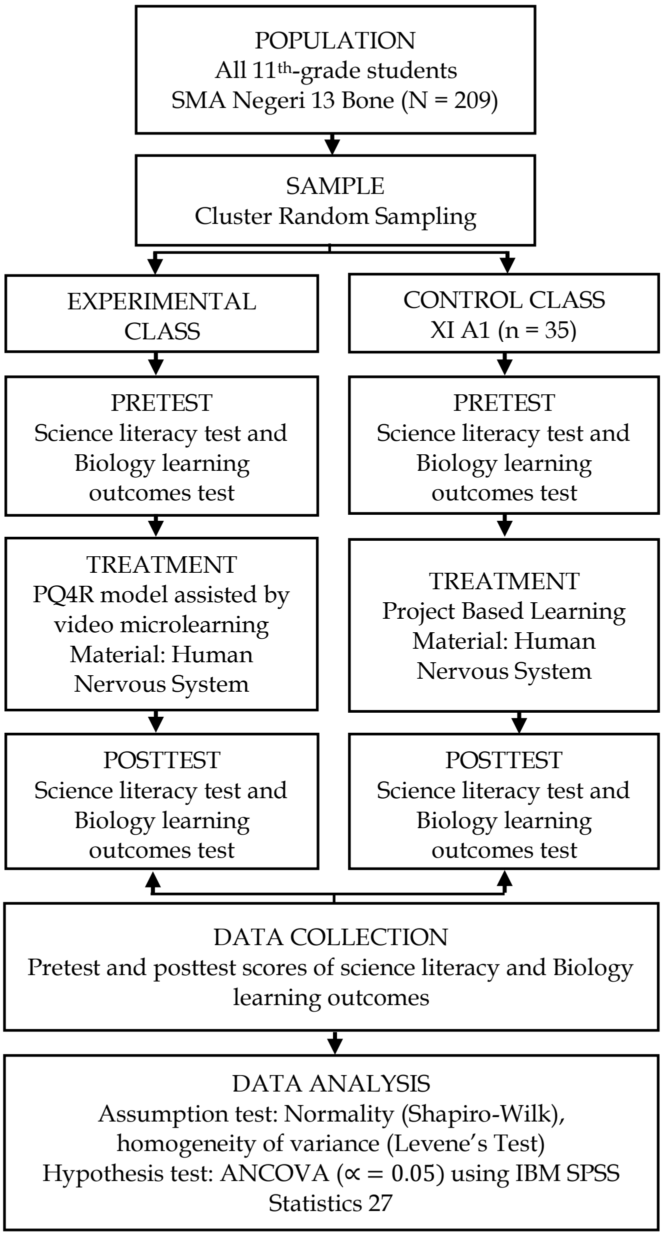
understanding, applying, analyzing, and evaluating biological concepts. All research instruments were validated by expert lecturers through expert judgment. Reliability test results showed a Cronbach's Alpha value greater than 0.70, thus declaring the instruments reliable for use in research.



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Result and Discussion

The study was conducted over six meetings on the human nervous system, involving two research groups: an experimental class using the PQ4R learning model assisted by microlearning videos and a control class using the Project-Based Learning (PjBL) model. Data analysis was conducted using descriptive statistics and analysis of covariance (ANCOVA) to determine the effect of the learning model on students' scientific literacy and biology learning outcomes after initial abilities were controlled.

The descriptive analysis showed that the initial scientific literacy skills of students in both groups were relatively equal before the treatment was administered. The average pretest score for scientific literacy in the experimental class was 49.89, while the average score for the control class was 49.83. The very small difference in averages indicates that both groups had nearly identical initial scientific literacy skills.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Group	N	Pretest Mean ± SD	Posttest Mean ± SD
PQ4R assisted by video microlearning	36	49.89 ± 10.32	92.44 ± 3.55
Project Based Learning (PjBL)	35	49.83 ± 11.12	87.20 ± 4.53

After the treatment, both groups experienced an increase in scientific literacy. The experimental class achieved an average posttest score of 92.44, while the control class achieved an average score of 87.20. These results indicate that students learning using the PQ4R model assisted by video microlearning achieved higher scientific literacy outcomes than those learning using the PjBL model. The ANCOVA test results showed that the learning model significantly influenced students' scientific literacy after controlling for initial abilities. The F-value of 29.28 with a significance level of <0.001 indicates a significant difference in scientific literacy between the two learning groups. The partial eta-squared value of 0.30 indicates that the learning model contributed 30% to the variation in students' scientific literacy, categorizing it as a large effect size.

Biology Learning Outcomes of Students

The descriptive analysis revealed a difference in initial biology learning outcomes between the experimental and control classes before the treatment was administered. The average pretest score for the experimental class was 54.67, while the average pretest score for the control class was 44.23. This difference indicates that the initial abilities of the two groups were not completely equal before the learning treatment was administered.

Table 2. Descriptive Statistics of Biology Learning Outcomes

Group	N	Pretest Mean ± SD	Posttest Mean ± SD
PQ4R assisted by video microlearning	36	54.67 ± 9.27	93.33 ± 3.45
Project Based Learning (PjBL)	35	44.23 ± 12.04	87.89 ± 4.50

These differences in initial abilities formed the basis for the analysis of covariance (ANCOVA) used in this study. ANCOVA was used to control for the influence of initial abilities so that differences in posttest scores could be interpreted as the influence of the applied learning model, rather than solely due to differences in students' initial abilities. After the treatment was administered, both groups experienced improvements in biology learning outcomes. The experimental class achieved an average posttest score of 93.33, while the control class achieved an average score of 87.89. The improvement in learning outcomes in the experimental class was significantly higher than in the control class.

Table 3. ANCOVA Results

Variable	Source	F	Sig.	Partial Eta Squared
Scientific Literacy	Learning Model	29.28	<0.001	0.30
Scientific Literacy	Pretest	0.34	0.560	0.01
Biology Learning Outcomes	Learning Model	26.08	<0.001	0.28
Biology Learning Outcomes	Pretest	0.00	0.998	0.00

The ANCOVA test results showed that the learning model significantly influenced students' biology learning outcomes after controlling for initial abilities. The F-value of 26.08, with a significance level of <0.001, indicates a significant difference in biology learning outcomes between students learning using the PQ4R model assisted by video microlearning and those learning using the PjBL model. The partial eta-squared value of 0.28 indicates that the learning model contributed 28% to the variation in students' biology learning outcomes, categorizing it as a large effect size. These results indicate that the PQ4R model assisted by video microlearning has a better impact on biology learning outcomes than the PjBL model.

The improvement in students' scientific literacy in the experimental class demonstrates that the PQ4R model assisted by video microlearning is able to create a more focused and systematic learning process (Irdalisa et al., 2024). Each stage in the PQ4R provides students with the opportunity to gradually understand concepts through reading, asking questions, reflecting, and restating the information learned. This process helps students build connections between concepts so that their understanding is not simply rote (Putri & Mufit, 2023).

The use of video microlearning reinforces this process through visualizations of abstract and complex nervous system material (Fatih et al., 2024). Videos are used not only during the preview and review stages but also during the read and reflect stages to help students understand the mechanisms of nerve impulse transmission, neuron structure, and nervous system coordination more concretely. The use of videos at these stages helps students construct visual representations of concepts that are difficult to observe directly.

Figure 1. Preview Stage in PQ4R Learning

Figure 2. Question Stage in PQ4R Learning

Figure 3. Read dan Reflect Stage in PQ4R Learning

The research results show that the PQ4R model, supported by video microlearning, is more effective than Project-Based Learning in improving scientific literacy in the nervous system (Suryanti & Festiyed, 2023). The nervous system is abstract, conceptually dense, and requires strong conceptual understanding. This requires students to develop structured learning stages to gradually grasp the concepts.

The Project-Based Learning approach requires students to be directly involved in completing projects, leading some students to focus more on completing assignments than on reinforcing basic concepts. This situation has the potential to increase students' cognitive load, especially on material that requires detailed understanding, such as the mechanism of nerve impulses and neuron coordination.

The PQ4R model provides a more systematic learning stage, allowing students to grasp basic concepts first before developing their understanding at later stages. This gradual learning structure helps students better organize information and reduces the difficulty in grasping scientific concepts.

These research findings align with information processing theory, which explains that learning is more effective when students actively process, organize, and reflect on the information they receive. Video microlearning facilitates this process by presenting material in a concise, focused, and easy-to-understand format, ensuring students' attention is maintained throughout the learning process.

The results of the study showed that the biology learning outcomes of students in the experimental class were higher than those in the control class after the treatment was administered. This difference remained after initial ability was controlled using ANCOVA.

The difference in pretest scores between the experimental and control classes is recognized as one of the characteristics of quasi-experimental research that uses natural classrooms without individual randomization. This condition resulted in the initial abilities of the two groups not being completely equal before the treatment was administered. The use of ANCOVA was conducted to control for the influence of initial ability so that differences in posttest scores could be analyzed more objectively as an influence of the applied learning model.

The ANCOVA results indicated that initial ability did not significantly influence learning outcomes after the treatment was administered. This condition indicates that improvements in student learning outcomes were more influenced by the learning model than differences in students' initial abilities.

Figure 4. Recite Stage in PQ4R Learning

Figure 5. Review Stage in PQ4R Learning

The advantages of the PQ4R model are evident in each learning stage, which helps students gradually understand the material. The preview stage helps students develop an initial conceptual understanding. The question stage increases learning focus by formulating questions related to the material being studied. The read and reflect stage helps students connect new information with prior knowledge, strengthening conceptual understanding. The recite and review stage helps strengthen information retention and facilitates recall of previously learned concepts.

The abstract nature of nervous system material requires students to utilize visual aids during the learning process. Microlearning videos help explain the process of nerve impulse transmission, neuronal mechanisms, and nervous system coordination in more concrete terms. Presenting material in a concise and focused format helps students grasp concepts without experiencing information overload.

Project-Based Learning is an effective learning model for developing collaboration and problem-solving skills. However, in nervous system material that is dense in concepts and requires detailed understanding, a project-based approach tends to lead some students to focus more on completing the product rather than reinforcing basic concepts. This results in students' conceptual understanding not developing optimally. The PQ4R model, supported by video microlearning, provides a more structured learning process, allowing students to gradually understand concepts before applying them. This resulted in higher learning outcomes for students in the experimental class compared to the control class.

Research findings indicate that integrating reflective reading strategies and video microlearning can create more meaningful, focused learning, and align with the characteristics of complex biology material. The PQ4R model, supported by video microlearning, can be used as an innovative learning alternative to improve scientific literacy and biology learning outcomes for students at the high school level.

Conclusion

The implementation of the PQ4R learning model assisted by video microlearning significantly impacted students' scientific literacy and biology learning outcomes in the nervous system. Students who learned using the PQ4R model assisted by video microlearning achieved higher posttest scores than those who learned using the Project Based Learning (PjBL) model. The results showed that the systematic learning stages in the PQ4R model, along with the support of short and visual microlearning videos, helped students understand complex biology concepts more effectively. Although there were differences in initial learning outcomes between the two groups before the treatment was given, the results of the ANCOVA analysis showed that the effect of the learning model remained significant after initial abilities were controlled. These findings indicate that the PQ4R model assisted by video microlearning can help reduce the gap in students' initial abilities and support the achievement of more optimal learning outcomes. Further research is recommended to examine the effect of the PQ4R model assisted by video microlearning on long-term learning retention, as well as its application in asynchronous digital learning environments and other biology materials with different conceptual characteristics.

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Author Contributions

Conceptualization, methodology, formal analysis, investigation, data curation, visualization, and writing—original draft preparation, A.N.Y.; validation, writing—review and editing, F.D. and I.; supervision, F.D. and I. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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