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Developing PBL E-Learning with the Brainwriting Method to Improve HOTS and Learning Interest in the Circulatory System

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Abstract

This study aims to determine the feasibility, practicality, and effectiveness of PBL e-learning using the brainwriting method to enhance students' Higher-Order Thinking Skills (HOTS) and learning interest. This research employs a research and development approach using the ADDIE model. The research instruments included media validation sheets from material and media experts, questionnaires, observation sheets, and test questions. The research results are as follows: (1) PBL e-learning with the brainwriting method is feasible for enhancing students' HOTS and learning interest; (2) this e-learning is practical for use in learning activities, as indicated by assessments from students and teachers, with a practicality score of 98, categorized as "very practical"; and (3) this e-learning is effective in improving students' HOTS and learning interest, as shown by the MANOVA test results, with a significance value of 0.000 (< 0.05). These findings suggest that integrating Problem-Based Learning (PBL) with the brainwriting method in an e-learning environment can be an effective instructional strategy to foster higher-order thinking skills and increase students' engagement in biology learning. Furthermore, this study contributes to the achievement of the Sustainable Development Goals, particularly SDG 4 (Quality Education), by promoting inclusive, innovative, and technology-enhanced learning practices that support the development of critical thinking skills essential for lifelong learning in the 21st century.

***Keywords**: Brainwriting, E-Learning, HOTS, Learning interests, Problem-based learning*

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INTRODUCTION

The rapid developments in science and technology have resulted in profound and far reaching changes, which require individuals as well as organizations to be perpetually responsive towards the global metamorphosis. The advent of these technologies has also had a profound effect on many aspects of human life, such as education, and influenced the way instruction is delivered, learning processes are performed , and educational media are used. Technology integration in education has gained importance as key instrument to respond and meet the demands of twenty-first century, nurturing educational system like innovation, adaptability, digital skill and pedagogical change both classroom and online environments. (Sain et al., 2024; Bellas et al., 2024; OECD, 2025). As such, altering pedagogical systems through successful use of educational technology is key to preparing students also for the challenges of a globally connected world. These approaches can help meet the needs of the twenty-first century by incorporating scientific and technological progress into education.

To meet the twenty-first century demands, students are supposed to acquire skills that raise the quality of life personally and academically. In The International Commission on Education for the Twenty-First Century of UNESCO, sustainable education is recommended to enhance self-quality and derived from these four pillars; learning to know, learning to live together, learning to be (self-realization) and learning to do [Agee et al. (Mulyani & Haliza, 2021). This aligns with Mardhiyah et al. (2021), who argue that education should balance knowledge and skills to cultivate quality students capable of adapting to the demands of the twenty-first century and the advancements of the Industrial Revolution 4.0.

The industrial revolution 4.0 requires the world of education to integrate digital

technology (Tri *et al*., 2021) as well as total changes ranging from ways of acting, learning strategies and thinking patterns. That is equally true for teachers and students, who need to be able to adjust and work together with each new era – which seems eminently feasible given the opportunities they now have to use new technology as a way of harnessing that desire for effective, efficient learning. Thus, the graduates who are born with those skills will be ready to sustainably meet industrial needs in the future of Industrial Revolution 4.0 (Santika, 2017). To celebrate the 4.0 industrial revolution era, the government, particularly in the education sector has introduced several policies including Curriculum 2013.

The implementation of the 2013 curriculum requires teachers to integrate four key aspects into learning: Strengthening Character Education, Literacy, 21st Century Skills (the 4Cs: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration), and Higher-Order Thinking Skills (HOTS). HOTS is one of the abilities that students must possess to answer the challenges of the 21st century. This aligns with Brookhart (2010), who argues that to meet the challenges of the 21st century, students need to not only remember and connect what they have learned but also "transfer" this knowledge for use or application in daily life, which requires a deep understanding of the learning material.

In an interview, a biology teacher stated that students' HOTS are still low. This is suspected to be because, at the beginning of learning, teachers attempted to apply HOTS assessments, but many students were unable to meet the requirements. As a result, teachers did not continue to train students using HOTS in subsequent lessons. This condition has affected the daily biology assessments of students, with 66.1% of students failing to reach the minimum completion criteria. This aligns with the results of a student questionnaire, which indicated that the circulatory system is one of the most difficult topics. Analysis of exam questions shows that students struggle to answer questions related to the circulatory system. According to the students, the difficulty arises because the material involves extensive memorization of processes, and the questions require analysis and application to real-life situations. Furthermore, during learning, students are not trained to analyze problems effectively.

Students who have not been trained to analyze problems are evident in classes where teachers rely solely on the lecture method at every session. In addition, teachers use learning media such as PowerPoint presentations, which are explained without providing feedback, and videos, which are shown without further interaction or explanation for students. This is suspected to make students' interest in learning in biology subjects low. Based on an interview with a biology teacher at a senior high school in Sleman Regency, it was found that some students were still using smartphones while the teacher was explaining the lesson. These observations indicate the need for strategies to increase students' learning interest and HOTS. One effective approach is the use of PBL e-learning integrated with the brainwriting method.

E-learning is highly effective in helping teachers manage interactive learning (Sam & Idrus, 2021). By integrating technology into education, e-learning can also help students who frequently use smartphones during learning to remain more focused (Iksan, 2018). Furthermore, research by Berlina (2020) shows that PBL can enhance students' HOTS by training their thinking processes and increasing their learning interest (Wicaksana et al., 2020). This is in accordance with the opinion of Komariah et al. (2019) that students' interest in learning can be seen in the needs and likes of students for lessons so that it is easier to understand concepts and analyze problems. Students are engaged in thinking activities through analysis and evaluation, enabling them to achieve indicators of high-order thinking skills (HOTS). The use of the PBL model is complemented by the brainwriting method, which helps students who are shy or reluctant to express their opinions to contribute ideas and generate diverse solutions when solving problems (Khairani & Aloysius, 2023).

The effectiveness of the digital brainwriting approach in this study is also shaped by its distinct instructional structure, which sets it apart from conventional discussion forums commonly used in Learning Management Systems (LMS). Unlike typical LMS discussion forums, which rely on voluntary, sequential, and often verbally dominated interactions, digital brainwriting requires all students to generate and submit ideas individually in written form before seeing their peers' responses. This structured idea-generation

phase minimizes social dominance, evaluation apprehension, and passive participation that frequently occur in open discussion forums, particularly among introverted or less confident students (Al-Saleh, 2022).

Furthermore, digital brainwriting emphasizes simultaneous and anonymous or semi-anonymous idea contribution, which encourages equitable cognitive participation and reduces the influence of hierarchical classroom dynamics. Research has shown that traditional LMS discussion forums are often dominated by a small number of active students, while others remain passive observers, limiting opportunities for higher-order cognitive engagement (Xie et al., 2023). In contrast, brainwriting fosters reflective thinking, idea elaboration, and iterative evaluation, as students analyze their peers' written ideas and refine their own responses. These processes are closely linked to core components of Higher Order Thinking Skills (HOTS), including analysis, evaluation, and synthesis (Paulus & Brown, 2022).

Therefore, the integration of the brainwriting method within the LMS in this study functions not merely as a digital discussion space, but as a pedagogically structured cognitive tool that systematically supports inclusive participation and deeper cognitive processing. This distinction helps explain why the experimental group showed significantly greater improvements in HOTS and learning interest compared to the control group, which did not engage in structured digital brainwriting activities.

The brainwriting method has disadvantages and advantages according to Sari (2021), namely: 1) The brainwriting method can be combined with other creative techniques to generate many ideas. 2) Help students who are quiet and less active in expressing opinions. 3) Generate more ideas than verbal opinions. 4) Reduce students' fear when expressing opinions that are not accepted by others. 5) Reduce the possibility of conflicts and misunderstandings between students. The disadvantages of the brainwriting method are 1) The brainwriting method has not been widely used and known to people, especially in the context of biology learning. 2) It causes the possibility of reduced interaction between students. 3) For students who don't like to write, it is difficult to express ideas. According to the opinion of Arsanti & Subiantoro (2020), the problem-based learning model combined with the brainwriting method has not been widely used and expressed during biology learning because there are still people who feel unfamiliar with the brainwriting method compared to brainstroming that is often applied.

The urgency of employing the brainwriting method in digital learning environments is further highlighted when compared to conventional oral brainstorming, which often dominates collaborative learning activities. In online or blended contexts, oral brainstorming can exacerbate common participation issues, such as unequal turn-taking, dominance by outspoken students, and reduced cognitive engagement among learners who are introverted or have lower verbal confidence. These challenges are amplified in digital settings where synchronous verbal interaction is limited by time constraints, technical barriers, and reduced social presence (Paulus & Brown, 2022).

In contrast, digital brainwriting emphasizes written idea generation, giving students ample time for reflection, analysis, and organization of their thoughts before sharing them with peers. This written format in a digital environment promotes deeper cognitive processing, encouraging students to articulate their reasoning, evaluate alternative ideas, and iteratively refine their responses. Empirical studies have shown that brainwriting generates a greater quantity and diversity of ideas than oral brainstorming and is more effective in promoting higher-order cognitive processes particularly analysis and evaluation, which are essential components of HOTS (Al-Saleh, 2022; Reiter-Palmon et al., 2023).

Moreover, in the context of LMS-based learning, brainwriting naturally aligns with asynchronous and semi-asynchronous interaction patterns, making it more pedagogically suitable than oral brainstorming. Its written format ensures inclusive participation by requiring every student to contribute ideas, thereby reducing social anxiety and evaluation apprehension that often hinder participation in verbal discussions. Consequently, digital brainwriting not only promotes equity in participation but also strengthens cognitive engagement, making it a strategically effective method for developing HOTS in technology-enhanced learning environments (Paulus et al., 2023).

In addition to the PBL learning process, LMS serves as a medium that can enhance

students' learning interest. This is consistent with research by Safitri et al. (2021), which found that Google Classroom-based electronic learning can increase students' interest in learning. Saputra (2022) stated that LMS is a solution to many problems that arise due to limited time, place and number of meetings between teachers and students so that it can increase the HOTS of students at a higher level in analyzing, re-evaluating the material that has been given and thinking critically in receiving various types of information. Therefore, this research is expected to provide a framework for the development of learning media in the form of PBL e-learning using the brainwriting method, which can effectively enhance HOTS and students' learning interest.

METHOD

This study employed a research and development (R&D) approach using the ADDIE instructional design model, which comprises five stages: analysis, design, development, implementation, and evaluation (Branch, 2009). The ADDIE model was applied to develop a PBL e-learning product integrated with the brainwriting method for teaching the circulatory system.

To examine the effectiveness of the developed product, this study employed a quasi-experimental design, specifically a non-equivalent pre-test post-test control group design. The product trial was conducted using this approach. Sample selection was carried out through cluster random sampling, in which two intact classes were randomly chosen: one class served as the control group, while the other served as the experimental group.

The data collection techniques in this study included interviews and observations, conducted to gather information about students to support the development of PBL e-learning using the brainwriting method. A test was also administered to measure students' ability to answer HOTS-based questions. The test instruments used are questions in the form of descriptions/essays that contain material on the respiratory system. This test was conducted both before (pre-test) and after (post-test) learning using PBL e-learning with the brainwriting method. Before being implemented in biology learning activities, the LMS-based E-learning media, designed using the PBL-oriented brainwriting method, were assessed by experts, including material and media experts, as well as practitioners, comprising biology teachers and students.

RESULTS AND DISCUSSION

The development of PBL e-learning using the brainwriting method on human circulatory system material for 11th grade was carried out using the ADDIE (Analysis, Design, Development, Implementation, & Evaluation) model. The results of the initial product development are presented according to each stage of the ADDIE model as follows.

Analysis

The needs analysis stage was conducted to identify the requirements of both teachers and students. Based on interviews with teachers, direct observations, and student needs analysis questionnaires, it was found that during biology lessons, teachers primarily use the lecture method in each session, showing videos without providing further explanations. Therefore, students tend to be less engaged during learning because they only listen without fully understanding the content of the videos. Furthermore, they have problems in understanding the co-circulation of the circulatory system, and become less interested in learning. Additionally, students do not understand HOTS questions. While teachers have introduced higher-order cognitive questions, many students, especially those with lower levels of background knowledge, experienced difficulty answering them at high success rates. This influences teachers not practising HOTS questions in every KD.

Based on the student needs analysis survey, 93% of students expressed interest in learning biology through a LMS that includes materials supported by images, supplementary resources, videos, and practice questions. Students also reported that the circulatory system was the most challenging topic, with 70% indicating difficulty. Therefore, it is necessary to develop PBL E-learning using the brainwriting method for circulatory system materials to enhance both HOTS and students' learning interest. This E-learning development can also help students use smartphones more effectively and wisely during the learning process.

The use of the PBL model with the brainwriting method aims to help students enhance their HOTS and learning interest. This aligns with the principle of the PBL brainwriting

method, which involves analyzing real problems and then writing about them, allowing students to develop knowledge, thinking skills, problem-solving abilities, and generate more ideas (Faturrohman, 2015; Amin & Sumendap, 2022). The difference between the use of the PBL brainwriting method in this study and previous studies is that, in this study, the PBL brainwriting syntax is integrated into the LMS. As a result, for each topic, students can publish and write their ideas directly on the LMS platform provided.

Design

The results of the design stage include the design of LMS features, learning tools such as learning designs, lesson plans, and teaching materials, as well as research instruments. The following figure presents a flowchart of PBL e-learning using the brainwriting method.

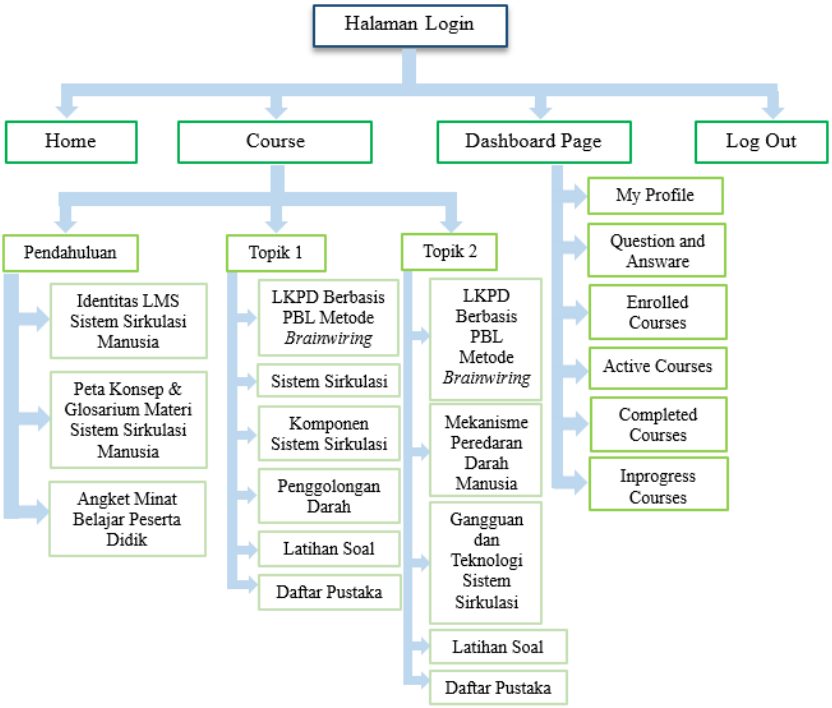

Figure 1. Flowchart of the media

The design of the human circulatory system materials is based on a curriculum analysis and is included in the E-learning platform in the form of an LMS. Additionally, the topic presented in the LMS focuses on the relationship between the COVID-19 vaccine and platelets, as well as drugs that can dissolve blood clots to prevent the risk of death. Meanwhile, the design of the research instrument is based on the results of teacher interviews, an analysis of student needs, and an analysis of student characteristics.

Development

This development stage was carried out according to the design established in the previous stage. After development, the product was first validated by media and material experts, and the results will be discussed in the product trial stage. In this study, the development stage produced a PBL E-learning product using the brainwriting method on the human circulatory system, in accordance with the planning from the previous stage. The results of the LMS feature development are presented as follows.

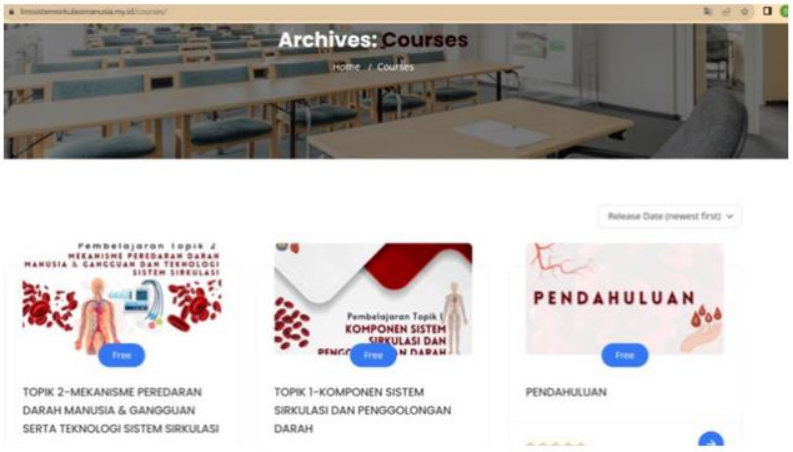

Figure 2. Course page

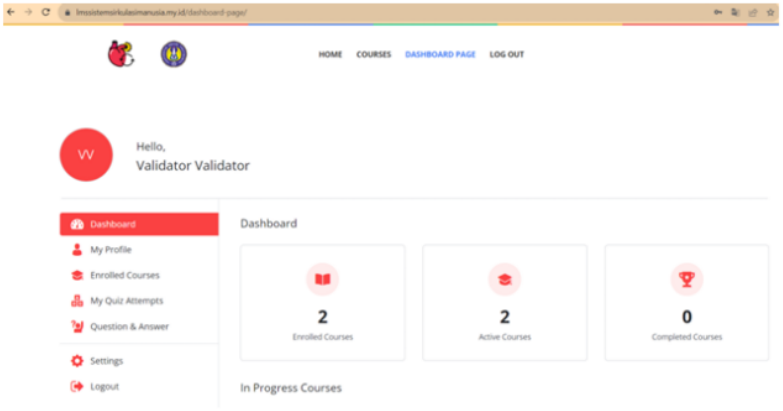

Figure 3. Dashboard page

At this stage, an assessment of the developed product's feasibility is conducted by experts in their respective fields. Following this evaluation, a valid and feasible product is obtained, ready for implementation in the learning process. The results of the product validation conducted by media experts are presented below.

Table 1. Validation result

Aspects	Score
Views	16
Software Engineering	12

Based on the results of the validation of PBL e-learning products using the brainwriting method, it can be concluded that the average score for the display and software engineering aspects is 4, which falls under the "very good" category. This assessment was conducted after the product had been revised according to the suggestions and feedback provided by the validator.

Implementation

The implementation stage was conducted after the product was tested on a limited group of science students. The next stage involved a broader trial, in which the practicality of LMS use was assessed by both teachers and students. The results of this practicality test are presented in Table 2.

Table 2. Practicality result

Aspects	Score		
	Teacher 1	Teacher 2	Student's
Content Eligibility	32	31	875
Language	15	15	442
Benefits	28	28	662
Graphic	24	23	668

Based on the results of the product practicality assessment by the teacher, the average score was 98, which falls within the very good/practical category. Meanwhile, the average score from students was 88.2, also classified as very good/feasible. Therefore, it can be concluded that PBL e-learning products with the brainwriting method are well-received and used smoothly by students.

Table 3. HOTS test result

Data Type	Experiment		Control	
	Pre-test	Post-test	Pre-test	Post-test
Number of Samples	30	30	30	30
Min Value.	19	56	19	28
Max Value.	47	84	53	63
Grade Average	30.60	68.97	30.03	48.53

Based on Table 3, the average HOTS pre-test and post-test scores in the experiment group were 30.60 and 68.97, respectively. In the control group, the scores were 30.03 for the pre-test and 48.53 for the post-test. A comparison of the average increase in pre-test and post-test scores between the experiment and control group is presented in Figure 4.

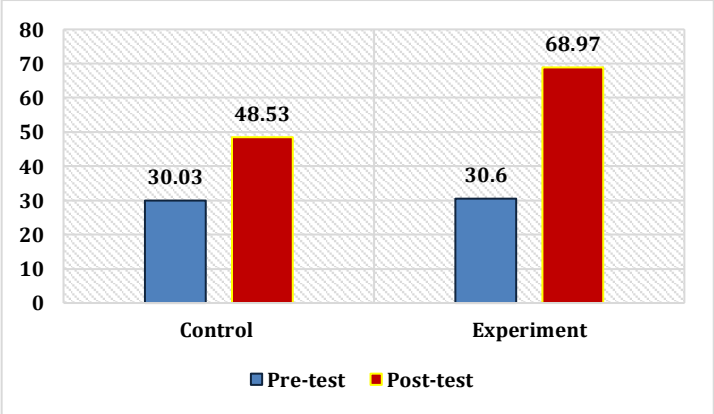

Figure 4. Comparison of HOTS scores

The comparison of the average increase in total pre-test and post-test scores of students' HOTS skills shows little difference overall. However, the posttest scores in the experiment group increased more substantially than those in the control group. This is also supported by the calculation of the n-Gain score in the experiment group, which is 0.55 in the medium category, but in the control group, the n-Gain score obtained is 0.26 in the low category. So, from the above statement, it can be concluded that PBL e-learning with the brainwriting method can increase the HOTS of students.

In addition to assessing students' HOTS levels, learning interest was measured using questionnaires administered before learning (pre-test) and after learning (post-test). The results of the data analysis on the implementation of PBL e-learning using the brainwriting method and its effect on students' learning interest are presented in Table 4.

Table 4. Learning interests result

Data Type	Experiment		Control	
	Pre-test	Post-test	Pre-test	Post-test
Number of Samples	30	30	30	30
Min	1	1	1	1
Max	4	4	4	4
Average	55.17	68.23	50.33	54.93

Based on Table 4, the average total learning interest score in the experiment group was 55.17 before the implementation of the LMS product and increased to 68.23 after the PBL e-learning with the brainwriting method was applied. In the control group, the average score increased from 50.33 before learning to 54.93 after learning. A comparison of the average increase in students' total learning interest scores is presented in Figure 4.

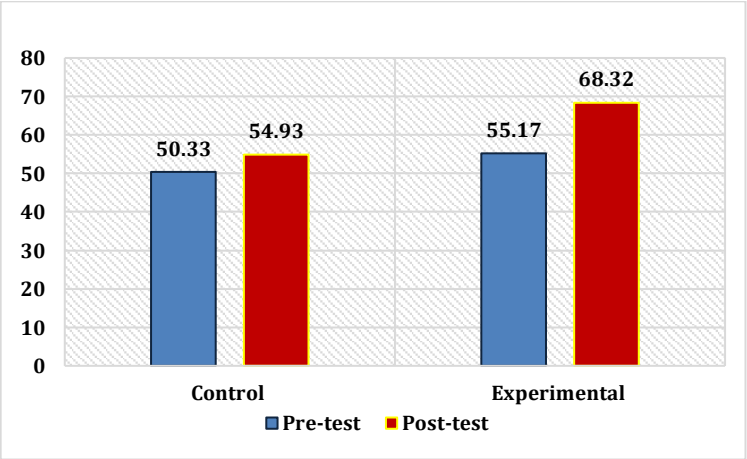

Figure 7. Comparison of learning interest score

Figure 7 shows the graph of the mean grey relation degree for the students' total learning interest scores. There was an increase not only in the experiment group but also in the control group, however, the positive change observed was insignificant for children in the control group. In detail, the control groups' average of this increase was only 4.6, whereas there was an even greater increase in the experimental group: Total scores which had initially been on average 55.17 rose to 68.32. This is also supported by the calculation of the N-Gain score in the experiment group, which is 0.31 in the medium category, but in the control group, the N-Gain score obtained is 0.09 in the low category. Thus, it can be concluded that the implementation of PBL-based e-learning with the brainwriting method in the experimental group effectively increases students' learning interest.

Although both the experimental and control groups showed an increase in students' learning interest, the improvement in the control group was considerably lower. This modest gain can be explained by the retention of traditional teacher-centred activities (lecture-based explanations, passive media presentation), that allow few moments of student interaction, autonomy and activity. Studies have demonstrated that traditional instruction may promote student understanding of fundamental content; however, it is generally less effective at promoting lasting interest in complex cognitive topics such as biology. (Wicaksana et al., 2020).

Moreover, the absence of structured collaborative and reflective learning activities in the control group restricted students' opportunities to actively express ideas, ask questions, and connect learning content with real-life problems. Learning interest is closely related to students' sense of involvement and perceived relevance; when instructional strategies do not provide meaningful participation or feedback, students' motivation and interest tend to increase only marginally (Hidi & Renninger, 2006; Schindler et al., 2022). Thus, the relatively low increase in learning interest in the control group can be attributed to limited learner-centered engagement and the absence of interactive learning features present in the PBL-based e-learning environment.

After obtaining the HOTS scores and students' learning interest data, a MANOVA test was conducted to analyze the hypothesis. The decision criterion adopted in the MANOVA test used Wilks' lambda value due to two dependent variables and since multivariate normality and homogeneity of variance-covariance matrices assumptions were satisfied by the data. The MANOVA test results are reported in Table 5.

Table 5. MANOVA result

Effect	Value	Error df	Sig.	Partial Eta Squared
Pillai's Trace	.816	57.000	.000	.816
Wilks' Lambda	.184	57.000	.000	.816
Hotelling's Trace	4.447	57.000	.000	.816
Roy's Largest Root	4.447	57.000	.000	.816

Based on Table 5, the results of the multivariate test using Wilks' Lambda indicate a statistically significant effect (Sig. = 0.000 < 0.05). Therefore, it can be concluded that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted. These results demonstrate a significant simultaneous difference in Higher Order Thinking Skills (HOTS) and learning interest between students who learned using PBL-based e-learning integrated with the brainwriting method and those who learned without this approach on circulatory system materials at the senior high school level in Sleman Regency.

The significant improvement in HOTS can be attributed to the characteristics of the brainwriting method implemented within the LMS, which provides students with structured opportunities to generate, articulate, and refine ideas in written form. Unlike oral discussions, brainwriting reduces social pressure and cognitive anxiety, enabling studentsparticularly those with introverted tendencies or lower verbal confidence, to actively engage in problem analysis and idea construction. Written idea generation in an asynchronous or semi-asynchronous digital environment promotes deeper reflection, evaluation of peers' ideas, and iterative problem-solving processes, all of which are core components of higher-order thinking (Al-Saleh, 2022; Khairani & Aloysius, 2023). Therefore, integrating brainwriting into PBL-based e-learning fosters equitable cognitive participation and supports the development of students' analytical and evaluative thinking skills.

The next stage of the MANOVA test is the between-subjects test. This test is used to determine the magnitude of the influence of LMS use on each research variable, namely HOTS and students' learning interest. The hypothesis test aims to determine whether there is a significant difference in HOTS and learning interest between students who participate in learning using PBL-based e-learning with the brainwriting method and those who learn without using this method on circulatory system materials. This hypothesis test was conducted by examining the results of the MANOVA between-subjects test, focusing on the significance values and partial eta squared data. The results of the between-subjects test are presented in Table 6.

Table 6. Test of the between-subjects result

Dependent Variable	df	Sig.	Partial Eta Squared
Minat Belajar	1	.000	.740
HOTS	1	.000	.543

Based on the results of the analysis of the Test of Between Subjects test, it can be concluded that the significance value of the HOTS variable is 0.000 < 0.05, then H0 is rejected and Ha is accepted. If H_a is accepted, it indicates that there is a significant difference in HOTS between students who learn using PBL e-learning with the brainwriting method on circulatory system materials and those who learn without using this method on the same materials. This shows that the learning media used in the experiment and control group have a significant effect on students' HOTS skills.

Furthermore, regarding the learning interest variable, the significance value is 0.000, which is less than 0.05. Therefore, H_0 is rejected, and H_a is accepted. This indicates that there is a significant difference in learning interest between students who learn using PBL e-learning with the brainwriting method on circulation system materials and those who learn without using PBL-based e-learning with the brainwriting method on the same materials. So that the media used in the experiment group and control influence students' learning interests.

Table 6 shows the results of the partial eta squared value for the students' learning interest variable. The obtained value is 0.740, which falls within the interval of > 0.197. Based on this range, it is included in the interpretation is very

strong, so it is concluded that the use of learning media in the form of PBL e-learning with the brainwriting method provides effectiveness in increasing students' learning interest based on the partial eta squared value.

The HOTS ability variable shows a partial eta squared value of 0.543, which falls within the interval > 0.197. Based on this range, the effect is interpreted as very strong, indicating that the use of PBL-based e-learning with the brainwriting method is highly effective in improving students' HOTS skills.

CONCLUSION

This development research produced a PBL e-learning model integrated with the brainwriting method on human circulatory system materials, which is feasible, practical, and effective in enhancing students' HOTS and learning interest. The feasibility of the product is demonstrated by expert validation results, which indicate very good ratings for content quality, media design, and instructional components. Additionally, the practicality of the developed e-learning is supported by positive evaluations from both teachers and students, showing that the learning media can be effectively implemented in biology learning activities. In addition, the efficacy of PBL e-learning with the brainwriting method is also evident in the significantly improved HOTS and learning interest among students as shown from the results of MANOVA analysis. These results indicate that combining problem-based pedagogical approaches with the use of collaborative concept mapping within a digital learning context can greatly contribute to improving students' cognitive and affective achievement. From a more global perspective, this study supports the realization of the SDGs, in particular SDG 4 (Quality Education), by fostering innovative, inclusive, and technology-enhanced learning approaches. Developed e-learning model promotes these three keys that are critical thinking, problem solving, and engagement of the learner, which are essential competencies in order to ensure lifelong learning, sustainable human resources development, and survival in the 21st century. Such PBL e-learning developed by a brainwriting method could be considered strategic for the sustainable, high-quality education, bearing an influence on the global trends in educational affairs.

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