

Unity 3D-Assisted Differentiated Problem-Based Learning versus Canva-Assisted Direct Instruction: Comparing Students' Learning Outcomes and Critical Thinking Skills

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ABSTRACT

This study aims to analyze the differences in learning outcomes and critical thinking skills between students receiving Unity3D-assisted, PBL-based differentiated instruction and those receiving Canva-assisted Direct Instruction (DI) in the fourth-grade Natural and Social Sciences (IPAS) subject, specifically regarding the topic of plant anatomy. The study employs a quantitative comparative approach and a quasi-experimental method using a posttest-only control group design. It was conducted at SD Negeri Blang Benara, Bener Meriah Regency, with a sample of 30 fourth-grade students comprising 15 in the experimental group and 15 in the comparison group selected via a saturated sampling technique. Data collection instruments consisted of a multiple-choice test for learning outcomes and an essay test for critical thinking skills. Data analysis utilized descriptive and inferential statistics via Multivariate Analysis of Variance (MANOVA) following the fulfillment of normality and homogeneity prerequisite tests. The results indicate a significant simultaneous difference between the two groups. Partial analysis revealed significant differences in both learning outcomes ($F = 43.737$; $\text{Sig.} = 0.000$) and critical thinking skills ($F = 46.840$; $\text{Sig.} = 0.000$). The group receiving Unity3D-assisted, PBL-based differentiated instruction demonstrated higher posttest scores compared to the group receiving Canva-assisted DI. These findings indicate that, within the context of this study, Unity3D-assisted, PBL-based differentiated instruction yields superior posttest results in both learning outcomes and critical thinking skills compared to Canva-assisted Direct Instruction.

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INTRODUCTION

Education plays a pivotal role in facilitating social mobility and advancing an inclusive society in Indonesia. However, the multifaceted challenges confronting the national education system pose significant obstacles to the provision of equitable and high-quality learning experiences that accommodate the diverse characteristics and needs of student. This issue is particularly apparent in Natural and Social Sciences (IPAS), where teachers play a critical role on managing classroom diversity and selecting instructional strategies that adress student heterogrnrity¹. Classroom practice indicate that teachers have not yet fully incorporated innovative instructional models that allign with the distinctive characteristics of Natural and Social Sciences (IPAS)². This highlights the impotence of addressing student diversity through contextualized IPAS instruction that promotes active student engagement while contributing to improved learning outcomes and the development of critical thinking skills.

The Merdeka Curriculum empowers educators to exercise greater flexibility and professional autonomy in designing meaningful and essential learning experiences³. This flexibility necessitates a classroom environment that responds to student diversity through the implementation of differentiated instruction. Philosophically, this approach aligns with Ki Hajar Dewantara's educational philosophy, which emphasizes child-centered education. In practice, differentiated instruction involves adapting classroom teaching and learning processes to meet the individual learning needs of each student⁴. By differentiating content, process, product, and the learning environment, teachers promote equitable access to learning opportunities, enabling each student to develop in accordance with their individual potential and characteristics.

The effective implementation of differentiated instruction in the classroom requires an instructional model that actively engages students in reasoning. In this context, Problem-Based Learning (PBL) serves as a student-centered instructional model. Fundamentally, PBL engages students with real-world problems, enabling them to construct their own knowledge, develop higher-order thinking skills, become more independent learners, and enhance

¹ Siti Nurhalizah and Putri Octa Hadiyanti, "Peran Guru dalam Menumbuhkan Keterampilan Berpikir Kritis pada Pembelajaran IPAS," *Murhum: Jurnal Pendidikan Anak Usia Dini* 6, no. 1 (2025): 128–142

² Asmaul Fauziah, Nurul Agustin, Ria Resti Fauziah, Rahmat Rudianto, Ainul Fithriyah, and Muhammad Luthfi Efendi, "Implementasi Model Pembelajaran PBL (Problem Based Learning) Berbasis Fenomenologi pada Pembelajaran IPAS untuk Meningkatkan Berpikir Kritis Siswa Madrasah Ibtidaiyah," *InsightEd* 1, no. 2 (2026): 115–125

³ Badan Standar, Kurikulum, dan Asesmen Pendidikan, *Kajian Akademik Kurikulum Merdeka* (Pusat Kurikulum dan Pembelajaran, 2024)

⁴ Wiwin Hervina, "Optimalisasi Kebutuhan Murid dan Hasil Belajar dengan Pembelajaran Berdiferensiasi," *Perspektif Ilmu Pendidikan* 35, no. 2 (2021): 175–182

their self-confidence.⁵ PBL serves not merely as an instructional option but as an ideal pedagogical framework for integrating differentiated instruction. The integration of these approaches is pedagogically justified by the potential to enhance student motivation when problem-based learning is implemented through process differentiation, allowing students to engage in learning activities that align with their preferred learning styles. In this context, teachers facilitate access to learning resources that correspond to students' individual ways of learning.⁶ Through this integration, differentiated instruction provides personalized support and task differentiation aligned with students' individual abilities, while the real-world problems presented in PBL effectively encourage students to develop their critical thinking skills and improve their learning outcomes in IPAS.

Therefore, interactive learning media are needed to support the implementation of differentiated instruction within the PBL framework. One technology with the potential to address this need is Unity3D, which enables the development of three-dimensional objects and immersive visual interactions, making abstract concepts more tangible. These features are particularly relevant to the study of plant anatomy, as certain plant structures and components may be difficult for students to comprehend through two-dimensional images alone. Previous studies have utilized Unity3D to develop instructional media for teaching plant structure and function. One such study developed an augmented reality (AR) learning medium using Unity3D and Vuforia to visualize plant structure and function. Other studies have likewise demonstrated the potential of AR technology to facilitate more interactive visualizations of plant structures^{7, 8}. Accordingly, Unity3D may be considered a promising technological tool for facilitating the visualization of plant structures. Nevertheless, its instructional effectiveness requires empirical investigation that accounts for the characteristics of the subject matter, the pedagogical approach employed, and the learners involved in the present study.

The use of Unity3D enables developers to create interactive learning media through three-dimensional representations that students can observe and

⁵ Irfan Supriatna, Herman Herman, Neza Agusdianita, Yusnia Yusnia, and Rizqa Dwi Shofiya Maghfira Izzania, "Model Problem Based Learning Terdiferensiasi sebagai Upaya Meningkatkan Kemampuan Pemecahan Masalah Mahasiswa," *Social, Humanities, and Educational Studies* 7, no. 3 (2024): 2525–2534

⁶ Nuzulatul Waliyah Rahmawati, She Fira Azka Arifin, and M. Amin, "Pengaruh Model Pembelajaran Problem Based Learning pada Pembelajaran Diferensiasi Proses untuk Meningkatkan Motivasi Belajar Peserta Didik pada Pembelajaran IPAS di MI Tambak Sumur Waru," *Jurnal Kolaboratif Sains* 7, no. 9 (2024): 3512–3519

⁷ Erti Hamimi, Sugiyanto, Erni Yulianti, Vita Ria Mustikasari, and Novida Pratiwi, "The Validity of Learning Material Assisted Augmented Reality Technology in the Topic of Structure and Function of Plant Tissue," *Jurnal Pembelajaran Sains* 5, no. 1 (2021): 1–6

⁸ Ayu Putri Herwidiah, Syamswisna, and Asriah Nurdini Mardiyanningsih, "Augmented Reality of Food Plants as a Biodiversity Learning Media for 10th Grade High School: A Feasibility Analysis," *Assimilation: Indonesian Journal of Biology Education* 6, no. 2 (2023): 85–96

explore. Three-dimensional learning media also have the potential to enhance student engagement, strengthen conceptual understanding, and provide more concrete learning experiences. This integration allows students to access and explore learning materials through interactive three-dimensional visual representations, with levels of instructional support and learning activities adjusted to their readiness and individual needs. Rather than receiving identical information in a uniform manner, students are guided to observe, explore, discuss, and solve problems according to their respective levels of readiness and group characteristics. Differentiation is implemented not by providing each student with a different medium, but by adjusting learning activities and the level of support provided during the use of Unity3D. Students who require additional assistance receive guidance and prompting questions while exploring three-dimensional objects, whereas those who demonstrate greater readiness are encouraged to explore the objects more independently and solve problems of greater complexity.

Direct Instruction differs substantially from differentiated instruction. It is a structured, teacher-centered instructional model in which content is delivered explicitly and uniformly to all students, making it effective for teaching foundational skills and factual knowledge⁹. Its implementation requires teachers to model the targeted knowledge or skills through carefully sequenced instructional steps. Common instructional activities include lectures, demonstrations, guided training, practice, and collaborative group tasks.¹⁰. In this approach, teachers act as the primary source of information and are expected to select and utilize instructional media that align with the classroom dynamics and learning conditions.

Canva-assisted Direct Instruction (DI) was selected as the comparison condition because comparative research requires an instructional approach that is pedagogically distinct from the experimental treatment while remaining aligned with the intended learning objectives and the characteristics of the learners. Direct Instruction is characterized by the systematic, explicit, and stepwise presentation of instructional content, incorporating teacher-provided examples, guided practice, and independent practice¹¹. These pedagogical characteristics establish Direct Instruction as a relevant comparator for differentiated instruction integrated with Problem-Based Learning (PBL). Whereas Direct Instruction

⁹ Stevanli Tatia, James U. L. Mangobi, and Ontang Manurung, "Perbedaan Hasil Belajar Materi Bangun Ruang Sisi Datar Siswa yang Menggunakan Model Problem Based Learning dengan Model Direct Instruction di SMP Negeri 2 Langowan," *Journal on Education* 6, no. 1 (2023): 8959–8966

¹⁰ Ni Made Sri Murjani, "Penerapan Model Pembelajaran Direct Instruction dengan Media Gambar untuk Meningkatkan Prestasi Belajar IPS," *Jurnal Penelitian dan Pengembangan Pendidikan* 3, no. 3 (2019): 264–270

¹¹ David Schuster, William W. Cobern, Betty AJ Adams, Adriana Undreiu, and Brandy Pleasants, "Learning of Core Disciplinary Ideas: Efficacy Comparison of Two Contrasting Modes of Science Instruction," *Research in Science Education* 48 (2018): 389–435

emphasizes structured content delivery, PBL-based differentiated instruction places greater emphasis on students' active involvement in identifying problems, exploring information, and constructing understanding through problem-solving. Previous studies in elementary science education have reported improvements in learning outcomes following the implementation of Direct Instruction, supporting its relevance as a comparison condition for examining alternative instructional approaches that emphasize active student participation.

Canva was used as a supporting medium in the Direct Instruction group to ensure that differences between the groups were not attributable solely to the use of instructional technology. Through images, infographics, presentations, videos, and other digital resources, Canva enables teachers to present learning materials visually. Previous studies have suggested that Canva-based learning media can support improvements in elementary students' motivation, academic performance, creativity, learning outcomes, and scientific literacy. Despite its visual and interactive features, Canva does not offer the same three-dimensional object exploration capabilities as Unity3D. Thus, Canva-assisted Direct Instruction was established as the comparison condition, representing structured and guided instruction supported by digital visual media. Meanwhile, Unity3D-assisted differentiated instruction based on PBL emphasizes problem-solving, exploration, active engagement, differentiated learning experiences, and three-dimensional object visualization.

The use of instructional approaches and learning media that are appropriate to students' needs and characteristics can influence their cognitive learning outcomes. Learning interest has been recognized as a key factor influencing students' learning motivation and academic achievement.¹² Learning outcomes represent the abilities that students develop after engaging in learning experiences over a specified period. These outcomes can be assessed through systematic evaluation and encompass cognitive, affective, and psychomotor dimensions, which collectively serve as important indicators of educational achievement.¹³ Students' learning outcomes reflect the abilities they acquire through learning experiences and can be measured through assessment. They constitute an important indicator of educational success across the cognitive, affective, and psychomotor domains.

Based on a preliminary study involving observations and interviews with a fourth-grade teacher, students' learning outcomes in the topic of plant structures and functions were found to remain below the learning achievement benchmark established by the school. The initial assessment results indicated that students

¹² Tuesday Tri Wardani, Suparji, and Agus Wiyono, "Pengaruh Model Pembelajaran Direct Instruction Berbantuan Multimedia Interaktif terhadap Pemahaman Konsep Siswa pada Elemen Gambar Teknik Siswa Kelas X DPIB SMK 3 Surabaya," *LEARNING: Jurnal Inovasi Penelitian Pendidikan dan Pembelajaran* 4, no. 4 (2025): 1301–1312

¹³ Tasya Nabillah and Agung Prasetyo Abadi, "Faktor Penyebab Rendahnya Hasil Belajar Siswa," *Prosiding Sesiomadika* 2, no. 1c (2020)

obtained a mean score of 65, whereas 75 was the benchmark used by the school to determine the attainment of learning outcomes. Thus, a 10-point gap existed between the students' mean score and the established benchmark. These findings indicate that students' understanding of plant structures and functions requires further improvement.

One of the issues identified in the preliminary study was that classroom instruction remained predominantly teacher-centered, with teachers serving as the primary source of information, while students had limited opportunities to explore objects, engage in discussions, and participate actively in the learning process. This situation highlights the need for a more student-centered instructional approach supported by learning media that can represent plant structures and functions in a concrete and interactive manner. These preliminary findings provided the basis for examining Unity3D-assisted differentiated instruction based on Problem-Based Learning (PBL) as a potential approach to improving students' learning outcomes and critical thinking skills. Furthermore, the existing instructional practices did not fully accommodate differences in students' characteristics and learning needs. The teacher continued to employ a relatively uniform instructional approach, resulting in varying learning experiences: some students found the activities challenging and motivating, whereas others experienced difficulties keeping up with the learning process.

In addition to the issues concerning cognitive learning outcomes, the preliminary study, based on classroom observations and an interview with the fourth-grade teacher, also indicated that students' critical thinking skills in the topic of plant structures and functions might not have developed optimally. During the interview, the teacher reported that students tended to find it easier to memorize and identify plant parts than to explain the relationships between their structures and functions. Classroom observations further revealed that students' activities primarily involved receiving and recalling information presented by the teacher, while opportunities to analyze information, provide justifications, establish cause-and-effect relationships, and solve problems remained limited. These findings suggest a need to foster students' critical thinking skills through learning experiences that provide greater opportunities for active exploration, analysis, and problem solving.

The integration of differentiated Problem-Based Learning (PBL) with Unity3D interactive three-dimensional media is expected not only to help students develop a concrete understanding of concepts and improve their learning outcomes but also to foster critical thinking skills, particularly in analyzing, evaluating, and drawing conclusions about contextual problems related to plant organs.

A previous study entitled "A Comparative Study of Students' Learning Outcomes in the Pythagorean Theorem Taught Using Problem-Based Learning and Direct Instruction" found that students taught using Problem-Based Learning (PBL) achieved better learning outcomes than those taught using Direct

Instruction in Grade VIII mathematics at SMP Negeri 6 Tahuna. This finding was supported by the statistical hypothesis test, in which the calculated t-value of 3.113 exceeded the critical t-value of 1.701. However, one limitation of the study was that the instructional models were not supported by interactive digital learning media¹⁴. Previous studies have indicated that Problem-Based Learning (PBL) has the potential to improve elementary school students' cognitive learning outcomes and higher-order thinking skills. According to ¹⁵ found that the implementation of Problem-Based Learning (PBL) influenced elementary school students' critical thinking skills. Similarly, ¹⁶ found that the integration of PBL with Google Sites-based interactive multimedia could enhance students' critical thinking skills in science learning. Collectively, these findings highlight the potential of combining PBL with digital learning media to enrich the learning process. Nevertheless, the media employed in the latter study did not feature three-dimensional visualizations of learning objects.

Meanwhile, research on differentiated instruction suggests that integrating differentiation with Problem-Based Learning (PBL) can help accommodate diverse student needs in elementary school Natural and Social Sciences (IPAS) learning. Previous studies have examined the implementation of differentiated instruction integrated with Problem-Based Learning (PBL) in elementary Natural and Social Sciences (IPAS) education¹⁷. Another study applied PBL in differentiated IPAS instruction in Grade IV and reported improvements in academic performance and student engagement¹⁸. Despite their relevance to the present study, these studies did not incorporate Unity3D-based three-dimensional visualization media or compare this instructional approach with digital media-assisted Direct Instruction..

Meanwhile, research on educational technology suggests that interactive digital media and three-dimensional technologies may support students' understanding of objects or concepts that are difficult to observe directly. However, studies on instructional media have generally focused on media

¹⁴ Nindy Titania Bangki, James U. L. Mangobi, and Derel Filandy Kaunang, "Studi Komparasi Hasil Belajar Teorema Pythagoras Siswa yang Diajarkan Menggunakan Model Problem-Based Learning dengan Direct Instruction," *Jurnal Riset dan Inovasi Pembelajaran* 4, no. 2 (2024): 1159–1170

¹⁵ Yuliana Darmawati and Ali Mustadi, "The Effect of Problem-Based Learning on the Critical Thinking Skills of Elementary School Students," *Jurnal Prima Edukasia* 11, no. 2 (2023): 142–151

¹⁶ Galih Yoga Pradana, Neni Mariana, and RiFat Shafwatul Anam, "The Influence of the Problem-Based Learning Model Assisted by Google Sites Interactive Multimedia on Critical Thinking Skills in the Science Subject of Grade V Elementary School," *Jurnal Pendidikan Dasar Nusantara* 10, no. 1 (2024): 102–116

¹⁷ Ridiyanto, Daimul Hasanah, dan Heri Maria Zulfiati, "Implementasi Pembelajaran Berdiferensiasi dengan Model *Problem Based Learning* pada Mata Pelajaran IPAS Kelas IV SD Negeri 2 Banyuurip Temanggung," *Pendas: Jurnal Ilmiah Pendidikan Dasar* 9, no. 3 (2024)

¹⁸ Julia Adenti and Ryan Dwi Puspita, "Penerapan Model Pembelajaran Problem Based Learning (PBL) pada Pelajaran IPAS Terdiferensiasi di Kelas IV," *Pendas: Jurnal Ilmiah Pendidikan Dasar* 10, no. 2 (2025)

development or effectiveness without sufficiently examining their integration with specific pedagogical approaches. Accordingly, previous studies have investigated the role of PBL in developing critical thinking skills, the implementation of differentiated instruction through PBL, and the use of digital media in science education. Nevertheless, these three components have not been extensively investigated in an integrated instructional configuration.

Despite growing research interest in innovative instructional approaches and educational technologies, direct empirical comparisons between active learning integrated with three-dimensional media and conventional instruction supported by two-dimensional visual media remain limited in elementary Natural and Social Sciences (IPAS) education. Previous studies have generally examined Problem-Based Learning (PBL) or Unity3D-based media in isolation rather than comparing an integrated PBL-based approach with Direct Instruction supported by digital visual media. To address this gap, the present study compares Unity3D-assisted differentiated instruction based on PBL with Canva-assisted Direct Instruction. It aims to investigate differences in the effects of these two instructional configurations on Grade IV students' learning outcomes and critical thinking skills in IPAS. The study is expected to offer theoretical insights into the comparative use of instructional models and media, while providing educators with an evidence-based reference for making instructional decisions that account for learner diversity.

METHOD

The study was conducted with two groups: an experimental group and a control group. The experimental group received Unity3D-assisted differentiated instruction based on Problem-Based Learning over two sessions, whereas the control group received Canva-assisted Direct Instruction in one session. Both groups studied the same topic, namely plant structures and functions, with equivalent learning objectives and core content. The treatments differed in the instructional model, the implementation of differentiation, and the learning media used.

During the first session in the experimental class, students' initial abilities were assessed through a diagnostic assessment. The results were used by the teacher to determine the forms of differentiation to be implemented during instruction, particularly in terms of content and product, according to students' needs and characteristics. In the second session, instruction was delivered following the stages of Problem-Based Learning: orienting students to the problem, organizing students for learning, guiding investigation, developing and presenting work, and analyzing and evaluating the problem-solving process. Unity3D was used as a medium for three-dimensional visualization and object exploration during the investigation stage, enabling students to observe plant structures in a more interactive manner. The teacher provided varying levels of guidance and support according to students' needs, ensuring that differentiation remained integrated throughout the PBL process. After the instructional

sequence was completed, students took a posttest to measure their learning outcomes and critical thinking skills.

Meanwhile, the control class received Canva-assisted Direct Instruction in a single session. The instruction followed several stages: presenting the learning objectives, explicitly delivering the content, providing teacher-led demonstrations or explanations, conducting guided practice, checking students' understanding, and assigning independent practice. Canva was used to present instructional materials through images, text, illustrations, and visual information about plant structures and their functions. After the content delivery and practice activities were completed, students took a posttest using the same instrument administered to the experimental class.

This study employed a quantitative comparative research design using a quasi-experimental method. It aimed to compare Unity3D-assisted differentiated instruction based on Problem-Based Learning with Canva-assisted Direct Instruction in terms of students' learning outcomes and critical thinking skills. In the experimental class, differentiated instruction was implemented based on the results of a diagnostic assessment of students' prior knowledge, with differentiation applied to content and process. Content differentiation involved adjusting instructional materials and learning resources, whereas process differentiation involved varying the levels of guidance, learning activities, and ways in which students explored the material using Unity3D.

The study was conducted at SD Negeri Blang Benara, located in Bukit District, Bener Meriah Regency. The study population, which also served as the sample, consisted of 30 fourth-grade students, comprising 15 students from Class IV A and 15 students from Class IV B. The sampling technique employed was non-probability sampling, specifically total sampling.

This study employed a posttest-only group design, with Class IV A serving as the experimental group and Class IV B as the control group. Group assignment was determined in consultation with the school and classroom teachers; therefore, random assignment was not conducted. To enhance the comparability of the initial conditions, the two classes were selected based on relatively similar characteristics, including grade level, learning content, curriculum, and student characteristics. In addition, a diagnostic assessment was administered to the experimental group at the beginning of instruction to identify students' prior knowledge and determine their differentiation needs. The initial comparability of the two groups was also considered based on information about students' academic abilities and previous learning outcomes provided by the schoolteachers. Accordingly, differences in posttest results were interpreted in light of the initial conditions and the limitations of the posttest-only design, which does not directly measure differences in baseline abilities between the two groups.

The research instruments consisted of an initial diagnostic questionnaire, a learning outcomes test, and a critical thinking skills test. The initial diagnostic questionnaire was used to identify students' learning readiness and interests. The

diagnostic assessment results served as the basis for implementing content and process differentiation in the experimental class and were not analyzed statistically. The learning outcomes test comprised 30 multiple-choice questions developed in accordance with the learning objectives for the topic of plant structures and functions, covering cognitive levels C3–C6. The instrument was developed through the preparation of a test blueprint and individual items, followed by expert content validation and a pilot test to assess its validity and reliability. Each correct answer was awarded one point, while each incorrect answer received zero points. The critical thinking skills test consisted of five open-ended questions developed based on five indicators: providing simple explanations, developing basic skills, drawing conclusions, providing further explanations, and formulating strategies and tactics. Each question had a maximum score of four, resulting in a total maximum score of 20. A common scoring rubric was applied to all students to ensure scoring consistency. Both tests were administered to the experimental and control groups after the interventions using the same instruments.

Data analysis involved descriptive and inferential statistics using SPSS. Before being used in the study, each research instrument was tested separately. The multiple-choice learning outcomes test was assessed for item validity using the Product-Moment correlation and for reliability using the Spearman–Brown formula. The open-ended critical thinking skills test underwent expert content validation, while scoring reliability was addressed by consistently applying the same scoring rubric to all students. The diagnostic questionnaire was used to determine students' differentiation needs and was not analyzed as a research variable. The validity and reliability test results were reported based on the pilot sample size, acceptance criteria, and the number of items that met the established criteria.

Before hypothesis testing, the assumptions underlying MANOVA were examined, including data normality, homogeneity of variances using Levene's test, homogeneity of covariance matrices using Box's M test, relationships between the dependent variables, and potential multivariate outliers. Given that each group consisted of only 15 students, the results of the assumption checks were reported transparently to inform the interpretation of the MANOVA results. Hypothesis testing was conducted using MANOVA at a significance level of 0.05. A p-value below 0.05 was interpreted as indicating a statistically significant difference between the two groups in the combined outcomes of learning achievement and critical thinking skills.

The treatment variable in this study was conceptualized as two instructional configurations: Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction. Because the instructional model, implementation of differentiation, and learning media were applied simultaneously within each group, the study was not designed to isolate the individual effects of each component. Accordingly, the conclusions focus on

differences in the overall effectiveness of the two instructional configurations in relation to students' learning outcomes and critical thinking skills.

RESULT AND DISCUSSION

Result

The research data were obtained from posttest results collected from students in Classes IV A and IV B following the instructional interventions. Class IV A received Unity3D-assisted differentiated instruction based on PBL, whereas Class IV B received Canva-assisted Direct Instruction.

The posttest data on learning outcomes and critical thinking skills were subsequently analyzed to examine the score distributions and differences between the experimental and control groups following the instructional interventions. Because the study employed a posttest-only design, the analysis focused on comparing posttest scores between the two groups and was not intended to measure improvements from pre-intervention levels. Before hypothesis testing, preliminary assumption checks were conducted, including tests of normality and homogeneity of variances, as well as other relevant assumptions underlying MANOVA.

Descriptive Statistics of Learning Outcomes

Table 1. Descriptive Statistics of Students' Learning Outcomes

Group	N	Mean	Standard Deviation
Control	15	71,67	6,172
Experimental	15	86,67	6,172

As shown in Table 1, the control group achieved a mean learning outcome score of 71.67, with a standard deviation of 6.172, whereas the experimental group obtained a mean score of 86.67, with the same standard deviation of 6.172. Descriptively, the experimental group demonstrated a higher mean learning outcome score than the control group.

Table 2. Results of the Normality Test for Learning Outcome Data

Group	N	Sig.
Control	15	0,200
Experimental	15	0,200

As shown in Table 2, the One-Sample Kolmogorov–Smirnov normality test yielded a significance value of 0.200 for both the control and experimental groups' learning outcome data. Since both values exceeded the 0.05 significance level, the data from both groups were considered consistent with a normal distribution. Thus, the normality assumption was satisfied for this variable, allowing further statistical analysis to proceed.

After the data were found to be consistent with a normal distribution, the next step was to examine the homogeneity of variances between the experimental and control groups. This test was conducted to determine whether the posttest score

variances of the two groups were homogeneous. The homogeneity test was performed using SPSS Statistics version 25.

Table 3. Results of the Homogeneity Test for Learning Outcomes

Variable	Levene Statistic	df1	df2	Sig.
Learning Outcome	0,000	71167	27	0,997

The Levene's test for homogeneity of variances yielded a significance value of 0.997. Since this value exceeded the 0.05 significance level, the variances of students' learning outcome scores in the control and experimental groups were considered homogeneous. With the homogeneity of variance assumption satisfied, the analysis proceeded to MANOVA to examine whether a statistically significant difference existed between the experimental and control groups in the combined dependent variables of learning outcomes and critical thinking skills.

Table 4. Results of the Multivariate Test of Students' Learning Outcomes and Critical Thinking Skills

Effect	Multivariate Test	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	0,997	4455,224 ^b	2,000	27,000	0,000	,997
	Wilks' Lambda	0,003	4455,224 ^b	2,000	27,000	0,000	,997
	Hotelling's Trace	330,017	4455,224	2,000	27,000	0,000	0,997
	Roy's Largest Root	330,017	4455,224	2,000	27,000	0,000	0,997
Model	Pillai's Trace	0,766	44,073	2,000	27,000	0,000	0,766
	Wilks' Lambda	0,234	44,073	2,000	27,000	0,000	0,766
	Hotelling's Trace	3,265	44,073	2,000	27,000	0,000	0,766
	Roy's Largest Root	3,265	44,073	2,000	27,000	0,000	0,766

The multivariate test results based on Wilks' Lambda indicated a statistically significant simultaneous difference in learning outcomes and critical thinking skills between the experimental and control groups, $\Lambda = 0.234$, $F(2, 27) = 44.073$, $p < 0.001$, partial $\eta^2 = 0.766$. Thus, a multivariate difference was found between Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction in terms of the combined learning outcomes and critical thinking skills of students. The partial η^2 value of 0.766 indicates a large multivariate effect size.

Furthermore, the analysis was conducted on the critical thinking skills variable (Y2). The results of the Tests of Between-Subjects Effects showed an F-value of 46.840, with a significance level of $p < 0.001$. Therefore, a statistically significant difference in critical thinking skills was found between the two instructional groups. These univariate analysis results for Y1 and Y2 further clarify the MANOVA findings, which indicated a simultaneous difference in both dependent variables.

Table 5. Results of the Normality Test for Critical Thinking Skills

Group	N	Mean	Standard Deviation	Sig.
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Control	15	68,73	6,508	0,200
Experimental	15	84,80	6,349	0,200

Based on the results of the One-Sample Kolmogorov–Smirnov normality test, the critical thinking skills data for both the control and experimental groups had a significance value of 0.200. Since the significance values for both groups exceeded 0.05, the critical thinking skills data for the control and experimental groups were considered normally distributed.

Next, a homogeneity test was conducted to determine whether the variances in critical thinking skills scores were equal between the two groups before proceeding with hypothesis testing.

Table 6. Results of the Homogeneity Test for Critical Thinking Skills.

Levene Statistic	df1	df2	Standar Deviation	Sig.
0,002	1	28	6,508	0,961

Based on Table 5, the significance value was 0.961. Since this value exceeded 0.05, the variances in critical thinking skills scores between the experimental and control groups were considered homogeneous. With the assumptions of normality and homogeneity satisfied, the subsequent analysis could proceed to examine differences in critical thinking skills between the two groups.

After the critical thinking skills data were found to be normally distributed and to have homogeneous variances, the next step was hypothesis testing. This analysis aimed to determine whether a difference in critical thinking skills existed between students who received Unity3D-assisted differentiated instruction based on PBL and those who received Canva-assisted Direct Instruction.

Table 7. Results of the MANOVA Test for Critical Thinking Skills

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1936,033	1	1936,033	46,840	0,000
Within Groups	1157,333	28	41,333		
Total	3093,36	29			

Based on Table 6, the significance value was 0.000, which was below 0.05. Therefore, the null hypothesis was rejected and the alternative hypothesis was accepted. These results indicate a difference in critical thinking skills between the experimental and control groups. The findings suggest that Unity3D-assisted differentiated instruction based on PBL yielded different outcomes in students' critical thinking skills compared with Canva-assisted Direct Instruction.

Discussion

The findings revealed a statistically significant simultaneous difference in learning outcomes and critical thinking skills between Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction. Theoretically, the characteristics of PBL, which require students to identify

problems, conduct investigations, analyze information, and determine solutions, provide opportunities to develop critical thinking processes. These findings are also consistent with ¹⁹ which developed PBL within differentiated instruction for Grade IV learning on plant structures and functions. Differentiated instruction allows content and processes to be adapted to students' needs, while PBL provides learning experiences through problem-solving. The use of Unity3D further strengthens the visual dimension of learning, as ²⁰ demonstrated that Unity-based three-dimensional visualization can be used to present plant structures and functions in a more realistic and engaging manner.

Thus, this study contributes to the literature by examining two instructional configurations as integrated approaches: Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction, in relation to two outcomes simultaneously, namely learning outcomes and critical thinking skills. This approach complements previous studies that have tended to investigate PBL, differentiated instruction, or digital media separately. However, because the instructional model, differentiation, and media were implemented simultaneously within each group, the findings cannot establish the individual effectiveness of each component. Rather, they indicate differences in outcomes between the two instructional configurations as a whole.

Based on Table 1, the normality test results showed that the significance values for learning outcomes in both the control and experimental groups were 0.200. As these values exceeded 0.05, the learning outcome data for both groups were considered normally distributed. Furthermore, Table 2 showed a significance value of 0.997 for the homogeneity test, which also exceeded 0.05. This result indicates that the variances in learning outcomes between the two groups were homogeneous. With both assumptions satisfied, the learning outcome data were suitable for subsequent analysis.

In Table 4, the normality test results for critical thinking skills showed significance values of 0.200 for both the control and experimental groups. Since these values exceeded 0.05, the critical thinking skills data were considered normally distributed. Furthermore, Table 5 showed a significance value of 0.961 for the homogeneity test. As this value was greater than 0.05, the variances in critical thinking skills between the two groups were considered homogeneous. Thus, the critical thinking skills data also satisfied the assumptions required for subsequent analysis.

¹⁹ Riznaini Ika Utami, Fingka Wahyu Anggraini, Sulis Wahyu Ningsi, Divanny Aulia Hanif, and Wahyu Kurniawati, "Pendalaman Materi Bunyi dan Cahaya (Studi Kasus Penerapan Bunyi dan Cahaya dalam Kehidupan Sehari-hari)," *Konstanta: Jurnal Matematika dan Ilmu Pengetahuan Alam* 2, no. 1 (2024): 284–295

²⁰ Puja Lestari, Nirsal Nirsal, and Shindy Ekawati, "Rancang Bangun Visualisasi Objek 3D Menggunakan Teknologi Augmented Reality pada Pelajaran Struktur dan Fungsi Tumbuhan," *Prosiding SENDIKO (Seminar Nasional Hasil Penelitian & Pengabdian Masyarakat Bidang Ilmu Komputer)*, vol. 4 (2025)

The main test results are presented in Table 3 through the Multivariate Tests analysis. Under the Model section, all multivariate statistics, namely Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, yielded significance values of 0.000, which were below 0.05. These results indicate a statistically significant simultaneous difference in learning outcomes and critical thinking skills between students who received Unity3D-assisted differentiated instruction based on PBL and those who received Canva-assisted Direct Instruction.

These findings indicate that the differences between the instructional approaches were not limited to a single outcome measure but were evident simultaneously in learning outcomes and critical thinking skills. The Partial Eta Squared value of 0.766 for the model represents the multivariate effect size obtained in this study. Descriptively, these differences were also reflected in the posttest mean scores. For learning outcomes, the experimental group achieved a mean score of 86.67, compared with 71.67 in the control group. For critical thinking skills, the experimental group obtained a mean score of 84.80, whereas the control group achieved a mean score of 68.73.

These differences may be associated with the characteristics of the instructional approaches implemented in each group. Theoretically, differentiated instruction based on Problem-Based Learning (PBL) can provide a learning environment that enables students to engage in problem-solving activities while accommodating diverse learning needs. Engagement with problems, analytical processes, discussions, and solution-seeking in PBL is considered relevant to the development of critical thinking skills. Several studies have reported a positive relationship between PBL implementation and critical thinking skills, although its effectiveness may depend on instructional characteristics and contextual factors²¹.

Furthermore, differentiated instruction theoretically allows teachers to adapt learning content, processes, and products to students' needs and characteristics. A systematic review at the primary school level indicates that differentiated instruction has the potential to support analytical skills, decision-making, and reflection, which are associated with critical thinking skills. The integration of differentiated instruction with PBL has also been reported in previous studies as an approach that may support the development of critical thinking skills among elementary school students^{22 23}

The use of Unity3D as a visualization medium can also be considered a theoretically supportive factor, particularly for presenting science concepts with

²¹ Ling Yu dan Zuhana Mohamed Zin, "The Critical Thinking-Oriented Adaptations of Problem-Based Learning Models: A Systematic Review," *Frontiers in Education* 8 (2023)

²² Resti Umi Melinda, Fatkhur Rohman, Amrina Izzatika, dan Nelly Astuti, "Implementasi Model Problem Based Learning Terintegrasi Pembelajaran Berdiferensiasi untuk Meningkatkan Critical Thinking Skill Peserta Didik Sekolah Dasar," *Pendas: Jurnal Ilmiah Pendidikan Dasar* 10, no. 1 (2025)

²³ Waode Sitti Fatimah et al., "Enhancing Critical Thinking through Differentiated Instruction in Primary Education: A Systematic Literature Review," *Primary: Jurnal Pendidikan Guru Sekolah Dasar* 15, no. 1 (2026): 192–213

visual and spatial characteristics. Research on 3D visualization indicates that students' attention to 3D visual objects is associated with the learning process of scientific concepts, while studies on PBL supported by augmented reality technology suggest its potential to support problem-solving and decision-making skills. Therefore, in this study, 3D visualization can be positioned as a medium that supports the learning process and exploration of learning materials, rather than as a mechanism directly demonstrated to cause improvements in critical thinking skills²⁴

Therefore, the differences in critical thinking skills between the groups in this study are interpreted in relation to the differences in the instructional treatments, namely Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction.

Regarding critical thinking skills, the analysis results presented in Table 6 showed an F-value of 46.840, with a significance value of 0.000. Since this value was below 0.05, a statistically significant difference in critical thinking skills was found between the experimental and control groups. The experimental group achieved a mean critical thinking skills score of 84.80, whereas the control group obtained a mean score of 68.73. Thus, the findings indicate a difference in critical thinking skills between the two groups following instruction using different approaches.

The differences in critical thinking skills can be understood in relation to the characteristics of PBL, which provide students with opportunities to engage with problems, make observations, explore information, and seek solutions to the problems presented. The use of Unity3D in instruction also provides visual and interactive support for learning about plant structures, allowing students to engage in observation and exploration as part of their learning experience. These characteristics represent one aspect that may help explain the differences in critical thinking skills between the two groups.

Overall, the findings indicate a simultaneous difference in learning outcomes and critical thinking skills between Unity3D-assisted differentiated instruction based on PBL and Canva-assisted Direct Instruction. In this study, differentiation was implemented in terms of content and process by adapting material presentation and varying learning activities according to students' needs, as identified through an initial assessment. Theoretically, these adaptations may provide students with opportunities to understand and explore learning materials through experiences that align with their individual needs.

The integration of differentiation with PBL and Unity3D may also theoretically support student engagement in understanding problems, exploring learning materials, and developing critical thinking. However, the observed differences reflect the overall treatment of Unity3D-assisted differentiated

²⁴ Faruk Arici and Mehmet Yilmaz, "An Examination of the Effectiveness of Problem-Based Learning Method Supported by Augmented Reality in Science Education," *Journal of Computer Assisted Learning* 39, no. 2 (2023): 446–476

instruction based on PBL and therefore cannot be attributed separately to content differentiation, process differentiation, PBL, or Unity3D. The explanation of the role of differentiation is presented as a theoretical interpretation supported by previous research, rather than as a mechanism directly demonstrated by the study data.

CONCLUSION

Based on the research findings, it can be concluded that there was a statistically significant simultaneous difference in learning outcomes and critical thinking skills among students between the group receiving Unity3D-assisted differentiated instruction based on *Problem-Based Learning* (PBL) and the group receiving Canva-assisted *Direct Instruction*. The multivariate test yielded a significance value of 0.000, with a *Wilks' Lambda* of 0.234, $F(2, 27) = 44.073$, and a *partial eta squared* of 0.766, indicating a multivariate difference with a large effect size. Descriptively, the experimental group achieved a higher mean learning outcome score of 86.67 than the control group, which scored 71.67. Similarly, the mean critical thinking skills score was 84.80 in the experimental group, compared with 68.73 in the control group. For critical thinking skills, the test results also indicated a statistically significant difference, with $F = 46.840$ and a significance value of 0.000.

These findings indicate that the implementation of Unity3D-assisted differentiated instruction based on PBL yielded different outcomes compared with Canva-assisted *Direct Instruction* for both outcomes examined. However, these differences reflect the overall treatment configurations; therefore, this study cannot determine the individual contributions of differentiated instruction, PBL, or Unity3D. Accordingly, the findings should be interpreted as differences in outcomes between two integrated instructional configurations rather than as evidence of the effectiveness of each component independently.

Future research is recommended to involve larger sample sizes, longer implementation periods, and examinations of PBL-based differentiated instruction using digital media across different subject matter and student characteristics. These efforts are expected to provide stronger evidence regarding the consistency of the findings and broaden the applicability of the research results.

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