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Application of Project-Based Learning and Discovery Learning in Virtual Media on Analytical Thinking Skills for Animal Classification

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Abstract: This study aims to determine the characteristics of project-based learning and discovery learning virtual media on animal classification material and test the effectiveness of project-based virtual media discovery learning on animal classification material on analytical thinking skills. This research is a mixed type of research. The research design used is the exploratory sequential design, using qualitative data analysis as the initial stage and then used as a direction to determine the formulation of research problems, samples, and quantitative data collection methods, followed by the development of virtual media instruments based on project-based learning and discovery learning. Quantitative methods are applied using quasi-experimental research. The study design used a nonrandomized control group and a pretest-posttest design. The treatment class uses PjBL-based virtual media Iimplementation, the control class uses a virtual media discovery model-based. The test instrument used is an essay question to measure analytical thinking skills adapted from Brookhart. Data analysis using ANCOVA (p = 0.05%) with prates as covariates. The result of the differences in the characteristics of project-based learning and discovery learning virtual media lies in the syntax of learning models, virtual activities, work produced, and attitudes developed. The feasibility test results of both virtual media were declared suitable for use. The results of ANCOVA showed that project-based virtual media learning is more effective in improving analytical thinking skills than discovery-based virtual media learning.

Keywords: Analytical thinking; Animal classification; Cladogram; Discovery learning; Virtual media

Introduction

The ability to think at a higher level has become an achievement that must be obtained in learning objectives in the development of the learning process in the 21st century The ability to think at a higher level is applied to welcome the era of the ASEAN Economic Community (AEC). This is because in the ability to think at a higher level students are not only required to know but also critical thinking skills, creativity, and ability to solve problems and make decisions (O'Reilly et al., 2022). One of the higher-order thinking skills that a person must possess in the learning process is analytical thinking (Baten, 1918). Analytical thinking is a complex skill related to the process of identifying, separating, and differentiating based on sources of information that can be facts, evidence, hypotheses, concepts, assumptions, or conclusions (Pedaste et al., 2015). Analytical thinking requires skills to think in detail and accurately. The purpose of analytical thinking is to break matter into parts to determine the relationships between them. The analytical thinking aspect consists of three, namely

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thesis or statement, evidence, and reasoning and clarity (Brookhart, 2010).

The existing facts regarding analytical thinking skills based on previous research state that students do not have good analytical thinking skills (Kwangmuang et al., 2021). Based on the PISA (Program for International Students) survey in 2018, Indonesia is in the low category for reading, mathematics, and science skills (Naveed et al., 2023). Science ability, analytical thinking skills. Students in Indonesia who can achieve level 2 in science are 40% while the OECD average is 78%. Level 2 in the field of science in PISA assessment is related to aspects of analytical thinking, including being able to recognize an explanatory sentence (statement), using knowledge to identify cases based on explanations and scientific phenomena, and being able to make valid conclusions based on information or evidence (Dwivedi et al., 2023). PISA assessment data shows that people in Indonesia are largely unable to identify until concluding. The process of identifying to conclude is a sequence of analytical thinking processes.

Based on the results of initial observations of students, it is stated that analytical thinking skills are one of the skills needed to be able to understand the material. In contrast to the need for analytical thinking skills, students do not know correctly about the aspects of analytical thinking skills. In addition, based on the results of the assessment of students' analytical thinking skills, the results were still in the low category. Students more easily get high marks on low-level thinking skills (Anggraini et al., 2019; Tan et al., 2023). Low analytical thinking skills can be due to several factors, including the learning process, is unable to integrate the characteristics of analytical thinking skills, students do not know the aspects of analytical thinking, and students having difficulty identifying, organizing, and distinguishing information (Darling-Hammond et al., 2020).

Improving analytical thinking skills can be done by analyzing problems, discussing, identifying, making a decision, and drawing conclusions. Activities that can empower analytical thinking skills can be done by applying constructivism and collaborative learning (Pande et al., 2020; Zamiri et al., 2024). Learning models that are constructivism and collaborative learning are project-based learning (PjBL) and discovery learning (Alawi et al., 2019; Diana et al., 2021). One of the biological materials that is quite difficult to understand is taxonomic material (Arifin et al., 2019). The material requires a specific description so that students can understand the classification clearly. Students consider taxonomic material to have a wide scope so it requires clear examples or depictions so that it can be understood well and easily (Bond et al., 2021).

Taxonomy is a branch of learning in biology that is systematic. Systematics in classification is concerned with learning about the identification, naming (nomenclature), and classification of a living thing. The classification of an organism can be grouped based on physical or nonphysical characteristics. The concept of animal classification should not be rote but needs to be understood so that when students are faced with real circumstances, they will easily group the individual into the taxa sought. The concepts of animal classification are often not easily accepted, not only because of their characteristics but can occur for other reasons, affecting students' understanding of animal classification. One of the causes that often complicates the acceptance of concepts is the lack of explanation from sources. In addition, learning media can affect the acceptance of the concept of animal classification (Widodo et al., 2021).

The concept of classification of animal is not well understood by students. Based on preliminary observations, as many as 67% of students were unable to analyze and get the conclusion that mice, squirrels, moles, and house mice, are different animal species. Students who concluded that all five animals belonged to the same species gave reason because all five animals were both hairy, had mammary glands, and gave birth. These traits are not characteristic of the taxa part of the species, but rather characteristic parts of the class taxa. Animal classification material requires a specific description so that students can understand the classification clearly. Students consider animal taxonomy material to have a wide scope so it requires clear examples or depictions so that it can be understood well and easily. The results of initial observations show that the learning media used so far are only existing PowerPoint and printed books. The media used are not equipped with diverse examples to facilitate students' understanding of animal taxonomy material.

The selection of teaching materials and the way of delivering the material affect students' understanding of animal classification material. The teaching materials used must be able to meet the characteristics of animal classification materials. The characteristic of animal classification material that needs to be considered in the preparation of teaching materials is the existence of animal visualization that can be accessed at any time by students to be able to describe and analyze the characteristics of these animals without time limits (Willi et al., 2019). The teaching materials needed can be embedded in virtual learning media. Virtual learning media can be accessed by students anywhere and anytime.

In addition, this learning media has other advantages, namely being able to display video and sound (Valletta et al., 2017). Virtual learning media makes it easier for students to access other learning

resources, in animal classification materials, other internet-based sources are needed to assist students in analyzing animal characteristics so that students can group these animals (Gee et al., 2017). Virtual media is an electronically integrated learning media so that everyone (students) can communicate and discuss even though they do not meet directly with the help of the internet. Virtual media can accommodate a person's ability to observe, analyze, solve problems, think critically, to think creatively (Brahler et al., 2002).

Based on the background that has been described, this study aims to determine the characteristics of virtual media based on project-based learning and virtual media based on discovery learning, as well as test the effectiveness of the two virtual media on analytical thinking skills.

Method

This research is a type of mixed-method research. The research design used is the exploratory sequential design, using qualitative data analysis as an initial stage and then used as a direction to determine the formulation of research problems, samples, and quantitative data collection methods, usually followed by the development of theories or instruments (Grand-Guillaume-Perrenoud et al., 2023). Qualitative methods are used as an analysis of initial needs in developing teaching materials in the form of products. Quantitative methods are used to measure the effectiveness of such products. The products developed in this study are virtual media for project-based learning and discovery learning animal classification materials to empower students' analytical thinking skills.

The samples used were two classes, taken from the population by cluster random sampling technique. This technique takes a group of individuals, rather than individually taking members of the population into a research sample (Busetto et al., 2020). Thus, all members of the population have the same probability of being selected as members of the sample. The sample used amounted to 64 students, with each group consisting of 32 students. The study design was a nonrandomized control group, pretest-posttest design. Testing was carried out using prates and post-tests in two class groups, namely the experimental class using PjBL-based virtual media and the control class using discovery learning-based virtual media. The design of the research design can be seen in Table 1.

Table 1. Research Design

Group	Pretest	Variable	Posttest
Control	Y1	X1	X1Y2
Experiment	Y1	X2	X2Y2

Information:
Y1 = Value pretest analytical thinking skills
X1 = Application of virtual media based on discovery learning
X2 = PjBL-based virtual media deployment
X1Y2 = Posttest scores of discovery-based virtual media analytical thinking skills
X2Y2 = Posttest scores of PjBL-based virtual media analysis thinking skills

This study used a written test instrument to measure students' analytical thinking skills with 6 long answer description questions adapted from (Essien et al., 2024). Written tests are conducted to obtain pre and post-test scores. In addition, the instrument used is virtual media syntax with project-based learning and discovery learning models. All instruments in the study have been tested for validity. The validity of the instrument is carried out in several ways. The first way is with expert assessment. Expert assessment is an assessment of the feasibility of product design by experts in their fields. Expert assessment includes constructs of learning tools and evaluation questions. The second way is to test the test question instrument with the RASCH method. The instruments used in this study have been declared valid and fit for use.

Data analysis techniques are used in the form of qualitative and quantitative data analysis. Qualitative data analysis is carried out manually inductively with coding methods (Bingham, 2023). Quantitative data analysis using inferential statistical analysis using SPSS. Data analysis using ANCOVA Test with pretest value as a covariate. The prerequisite tests performed before the ANCOVA Test are normality and homogeneity tests.

Result and Discussion

Characteristics of Virtual Media Based on Project-Based Learning (PjBL) and Discovery Learning

Virtual media development is structured based on PjBL learning syntax and discovery. The PjBL syntax was adopted based on (Bingham, 2023) and the discovery syntax. A comparison of the characteristics of virtual media used in the study can be seen in Table 2.

Table 2. Comparison of Virtual Media Characteristics Based on Project Based Learning (PjBL) and Discovery Learning

Comparison Indicators	PjBL	Discovery Learning
Syntax	Planning an investigation process according to driving questions, Searching for the theoretical background of the driving questions, presenting that theoretical background to class and discussion about issue, deciding the study group the way of collecting data and data analysis, evaluating data, arriving a conclusion, presenting the project in class as preferred, and discussion	orientation hypothesis generation, hypothesis testing conclusion regulation
Material	Animal Classification Clarogram Making	Animal Classification
Duration	3x45 minute	3x45 minute
Virtual Activities	Clarogram Making Presentation	Presentation
Knowledge	Analytical Thinking Test (pretest and posttest)	Analytical Thinking Test (pretest and posttest)
Skills	Analytical Thinking Skill	Analytical Thinking Skill
Attitude	Independent, Global Diversity, Creative, Critical reasoning.	Cooperative, honest, responsible, and disciplined.

The basic difference between the two virtual media is the syntax used and the virtual activities that students must do. The results of virtual activities carried out by students have been adjusted to the syntax needs of each learning model. The difference in the results of students' virtual activities can be seen in Figure 1 and Figure 2.

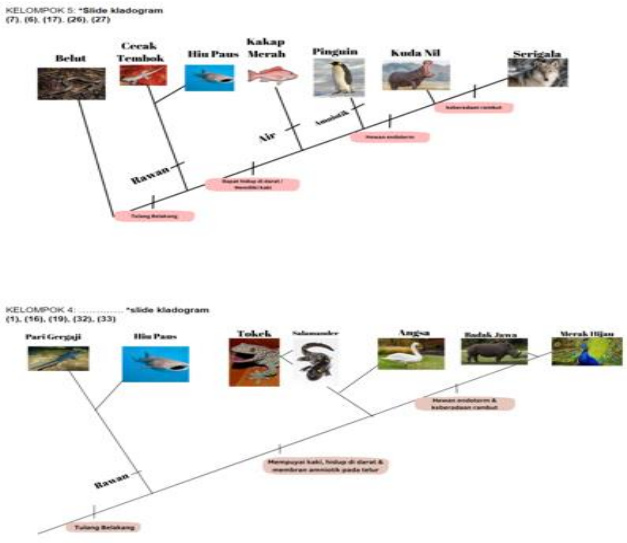

Figure 1. Result of PjBL virtual media activities

In PjBL-based virtual media, students conduct virtual activities in groups. Virtual activity refers to a project related to the classification of animals. The project made by students through virtual activities is making a cladogram from the names of animals that have been given by the teacher, students are asked to identify and analyze the characteristic characteristics of the animal then in groups compile a cladogram and present it.

Figure 2. Result of discovery virtual media activities

In virtual media based on Discovery Learning, students conduct virtual activities in groups to identify and analyze the characteristic traits of several animals that have been presented. The results of the virtual activity were worked on google slides and presented.

Feasibility of Virtual Media Based on Project Based Learning (PjBL) and Discovery Learning

The feasibility test of the learning device construct consists of six aspects, namely: identity; learning objectives; learning materials; selection of learning resources and learning media; assessment of learning outcomes; aspects of analytical thinking skills. The results of the feasibility test on the PjBL learning model

can be seen in Table 3 and the results of due diligence on the discovery learning model can be seen in Table 4.

Table 3. Feasibility Test Results on PjBL Learning Model

Aspect	Score	Category
Identity	100	Excellent
Learning objectives	88	Excellent
Learning materials	88	Excellent
Sources and media	88	Excellent
Assessment	88	Excellent
Aspects of analytical thinking skills	100	Excellent

Table 4. Feasibility Test Results on the Discovery Learning Model

Aspect	Score	Category
Identity	100	Excellent
Learning objectives	88	Excellent
Learning materials	88	Excellent
Sources and media	88	Excellent
Assessment	88	Excellent
Aspects of analytical thinking skills	88	Excellent

The test results by experts stated that the average was in the very good category. Based on the results of feasibility tests on virtual media, the PjBL learning model and discovery learning are declared feasible.

The Effect of Using Virtual Media Based on Project-Based Learning (PjBL) and Discovery Learning on Analytical Thinking Skills

Based on the analysis of the normality test with SPSS 16 on the Pre-test and Post-test scores of students' analytical thinking skills, it was found that the two groups used in the study had a significance value of 0.096. A significance value of >0.05 means that H0 is accepted, so the samples used in the study are declared normally distributed. Based on the analysis of the homogeneity test with SPSS 16 on the Pre-test and Post-test values of students' analytical thinking skills, it was found that the significance value was 0.191. A significance value of >0.05 means that H0 is accepted, so the sample used in the study has a homogeneous variance.

Table 5. ANCOVA Test Result

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	95.510a	2	47.75	5.39	0.007
Intercept	2164.59	1	2164.59	244.3	0
Prates	8.83	1	8.83	0.997	0.322
Class	87.83	1	87.83	9.913	0.002
Error	611.36	69	8.86		
Total	5657	72			
Corrected Total	706.87	71			

a. R Squared = .135 (Adjusted R Squared = ,110)

Data on analytical thinking skills in the study were analyzed using the ANCOVA test with the help of the SPSS 16 program. The results of the ANCOVA test of analytical thinking skills scores and types of virtual media can be seen in Table 5.

Teaching media that has a great influence on empowering students' analytical thinking skills is PjBL-based virtual media. This can be seen in the results of the difference in the average post-test results of students and the lowest and highest scores of students' post-test results in Table 6.

Table 6. Pairwise Comparisons

			95% Confidence Interval	
Group	Mean	Std. Error	Lower Bound	Upper Bound
Control	7.187a	0.496	6.19	8.17
Experiment	9.396a	0.496	8.4	10.38

a. Covariates appearing in the model are evaluated at the following values: Prates = 3.99.

Virtual media developed through both learning models both Project Based Learning (PjBL) and discovery learning has an increase in the value of analytical thinking skills, this is following previous research which states that constructivism and collaborative learning models can empower students' analytical thinking skills (Sudarsono et al., 2022). Media composed using virtual technology. In virtual media, group assignments are done through google slides which can be accessed when not during biology class hours. This is so that students in groups can connect virtually in discussions on assignments. Virtual discussions are intended to accommodate students' collaborative attitudes that can improve each student's analytical thinking skills (Labadze et al., 2023; Rehman et al., 2023; Rusdin et al., 2024; Singh et al., 2021).

The comparison in this study is the learning model used in both virtual media. Virtual media in the control class were arranged using the discovery learning model, while the experimental class virtual media used the PjBL model (Ismailov, 2021). Based on the results of statistical analysis tests, it was found that PjBL-based virtual media had a more significant increase in value than discovery learning-based virtual media. Virtual media arranged based on PjBL syntax aims to enable students to have analytical thinking skills through group activities to create a project in the form of a cladogram. PjBL has five stages, the five stages in PjBL can empower students' ability to analyze and group animals into their classification system.

The first stage is planning an investigation process according to driving questions. Students can identify different types of animals, determine specific markers on these animals, and formulate problem formulations to be solved (Nowell et al., 2017). This stage will

accommodate a person to raise initial questions as the initial process of achieving higher-order thinking skills and analytical thinking. At this stage, students have been invited to think about being able to compile statements related to classification, to accommodate thesis aspects in analytical thinking skills. The second stage is searching for the theoretical background of the driving questions. Students collect and analyze theories that can answer problem formulations. At this stage, students can come up with a thesis or statement that is compiled as an answer to the problem formulation, besides that student have been able to find the right evidence based on the thesis they put forward. So that in this second stage, the thesis and evidence aspects can be accommodated. The third stage is presenting that theoretical background to class and discussion about issue.

Students present the results of exploring the information that has been obtained and discuss it in groups. Discussion in groups is intended so that students get more evidence that can be used to answer problem statements, besides that students will learn to analyze together whether the evidence they get is by their answers. At this stage, it can accommodate two specs in analytical thinking skills, namely evidence, and reasoning. The fourth stage is deciding the study group the way of collecting data and data analysis. Students with group mates set one decision to start a project. The resulting project on this animal classification material is a cladogram of various types of animals with different taxon levels. At this stage, students must be able to collaborate to connect answers to problem formulations and information that has been obtained through an analysis process to be able to compile projects well (Tong et al., 2022). At this stage, it can strengthen students' ability to achieve aspects of evidence and reasoning in analytical thinking skills.

The last stage is evaluating data, arriving a conclusion, presenting the project in class as preferred, and discussing (Rahayu et al., 2019). At this stage, students can evaluate information data to compile a logically reasoned conclusion based on the project that has been produced (Almulla, 2020; Mahmud et al., 2023). The final stage is to present the results in class discussion. The last stage of PjBL can accommodate students' ability to compile a thesis and evidence that is true and coherent to be able to achieve the right reasoning. The five stages of the PjBL learning model can accommodate the training of every aspect of analytical thinking skills (Li et al., 2024). In addition, the project created by students has been adjusted to the material taught, namely making a cladogram on animal classification material.

The cladogram itself is a line that forms a tree diagram, the cladogram describes interspecies relationships based on characteristics or similarities. Cladograms can be made by students through the process of identification and analysis of data in the form of special characteristics of each given species. So that the existence of a project in the form of a cladogram is an important value in the PjBL model to accommodate the achievement of analytical thinking skills. The project is what distinguishes it from virtual media based on discovery learning. On virtual media that use discovery syntax, some syntax is unable to accommodate aspects of analytical thinking skills.

Discovery learning-based virtual media has five stages, including being able to accommodate analytical thinking skills. The first stage is orientation, students build their main concepts through literacy activities. The early stages of discovery have not been able to accommodate aspects of analytical thinking. The second stage is hypothesis generation with student activities to compile initial hypotheses regarding the classification of animal (Chigbu, 2019; Scossa et al., 2020). At this stage, students can write a statement as an initial hypothesis through the initial concepts they have. Thus, in the second stage of discovery learning can accommodate thesis aspects of analytical thinking skills.

The third stage is hypothesis testing, students collect data to carry out testing activities on hypotheses that have been compiled. Hypothesis testing is done by identifying some data as evidence. The third stage can accommodate the evidence aspect of analytical thinking skills. The fourth stage is conclusion, the concluding activity is carried out by students after analyzing whether the evidence obtained is following the hypothesis that has been made, and this is the same as the analysis process between the thesis and evidence to be able to write reasoning. Thus, at this stage, it can accommodate reasoning aspects in analytical thinking skills.

The last stage in discovery learning is the regulation or regulatory process to find out how students develop using the discovery learning model (Al Aliyawinata et al., 2021). The regulatory process can be used by teachers to determine the next steps in guiding students. At this last stage, it is not able to accommodate any aspect of analytical thinking skills. Based on a review of the series of syntax in discovery learning, the model has not been able to optimally accommodate analytical thinking skills such as the PjBL model. This is evidenced by the results of ANCOVA's further tests that PjBL-based virtual media have a greater influence than discovery learning-based virtual media on analytical thinking skills.

Conclusion

Based on the results and discussion, virtual media based on project-based learning and discovery learning

can both be used to improve analytical thinking skills. However, virtual media based on project-based learning has a more significant impact on increasing the value of analytical thinking skills as evidenced by the results of further statistical tests. Project-based learning virtual media has a syntax that can accommodate students' analytical thinking skills repeatedly compared to discovery learning syntax. Suggestions for further research require the development of similar virtual learning media using project-based learning syntax but with more practical applications for students so that students can make virtual cladograms more easily.

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The authors declare that there is no conflict of interest regarding the publication of this paper.

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