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Learning by Research: Building Critical Thinking and Analytical Skills in Developing a Scientific Learning Ecosystem

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Abstract. The low level of critical thinking and analytical skills among students is a rather critical issue**.** This study aims to analyse the effect of the learning by research model on improving students' critical thinking and analytical skills. The study uses a quantitative approach with a pretest-posttest design on groups that received research-based learning treatment. The instruments used were critical thinking tests and analytical skills tests that had been validated. Data analysis included descriptive statistics, normality tests, homogeneity tests, and multivariate analysis of variance tests to determine the simultaneous effect of the learning model on both dependent variables. Descriptive analysis results showed an increase in the average critical thinking and analytical skills scores after the implementation of learning by research. Normality and homogeneity tests showed that the data met the assumptions of parametric analysis. The Manova test results showed that the learning by research model had a significant simultaneous effect on students' critical thinking and analytical skills ($p < 0.05$). These findings indicate that research-based learning is effective in developing higher-order thinking skills through investigation, data analysis, and evidence-based argumentation activities.
Keywords: Learning by research, deep learning, co-curricular activities, critical thinking skills, analytical skills

Introduction

The number of formal researchers in Indonesia is still far fewer than in developed countries and lags behind several ASEAN countries, both in terms of the number of researchers and per capita research spending. The number of researchers in Indonesia per million inhabitants is only 1,071, which is below the world average of 1,420 per million in 2022. Compared to other ASEAN countries, Indonesia lags behind Singapore, Malaysia, Thailand, and the Philippines (Unesco, 2022). The low number of researchers in Indonesia is due to the Indonesian public's paradigm that research is difficult and only carried out by academics (Khuluqo & Pribadi, 2020). In addition, the low number of researchers is also due to low literacy rates (Asif et. al., 2025).

In fact, all man-made products are the result of research, so developing a habit of research is important. Research is not foreign to human life (Stoneman et. al*.*, 2018). Findings show that communities with high literacy levels correlate with high levels of scientific thinking (Apriliana & Anggrella, 2024). Scientific thinking is the foundation of research. Therefore, it is important to build and apply research values to students. In addition, research can also improve students' critical thinking (Thi, 2025) and analytical skills (Allanta & Puspita, 2021).

Research will stimulate critical thinking in students at the initial stage. The initial stage of research involves finding a theme or topic of interest. At this stage, students will observe their environment and stimulate their sensitivity to the phenomena around them. At this stage, critical thinking skills (CTS) begin to be honed. The knowledge that students already have is used to critique the phenomena to be studied. After that, students will formulate problems and look for solution ideas that will later be used to solve these problems. At this stage, CTS are developed (Abdulah & Gistituati, 2023).

In addition to CTS, research-based learning can foster students' analytical skills. Analytical skills in Bloom's taxonomy are at level 4 or high order thinking skills (HOTS). To achieve analytical skills, students must have knowledge, understanding, and be able to apply their knowledge in learning. Only then can students be said to have achieved analytical skills. In research-based learning, analytical skills are developed through critical thinking when students raise research themes or topics to be studied. Analytical skills are then honed through the coherence of students' understanding in synchronising the background, research methods used, and results obtained. When students explain the results they have obtained, they will deepen their analytical skills. Therefore, analytical skills are at the core of research activities. Analytical skills are not merely about making discussions, but rather about analysing problems, processing data, evaluating evidence, and then drawing logical conclusions, which are a series of analytical skills (Ocupa-Cabrera et al., 2025).

Students who possess strong critical thinking and analytical skills will correlate with strong metacognitive abilities and, of course, strong literacy skills as well. Literacy is closely related to critical thinking and analytical skills; one study found a correlation of approximately 0.80 between literacy and CTS (Susanti & Kridiana, 2021) and a correlation of 0.953 between literacy and analytical skills (Aziz & Septriyanti, 2023). Good literacy not only improves Indonesia's PISA scores but also reflects the quality of learning. Therefore, research-based learning is a new breakthrough in learning strategies and models.

Developing a scientific learning ecosystem centres on the direct integration of learning by research with the development of critical and analytical thinking skills within a holistic scientific learning ecosystem. Unlike previous approaches, which tended to separate learning models (such as problem based learning, project based learning, or inquiry based learning), this approach places research activities at the heart of the learning process, so that learners not only solve problems but also build knowledge through authentic and sustained scientific processes. This is supported by various international studies showing that research-based learning and scientific approaches can enhance students' cts, scientific literacy, and independent learning (Ramadhan & Mardin, 2023). Furthermore, global research trends indicate that the development of CTS in science education is on the rise and has become a key focus of 21st-century education, particularly in integrating analytical, evaluative and problem-solving skills within real-world contexts (Akbar et. al., 2024). Furthermore, recent studies have also confirmed that various exploration-based learning models, such as discovery learning and inquiry-based learning, are effective in enhancing critical thinking; however, they have not yet optimally fostered a sustainable, research-based scientific learning ecosystem (Agustini et. al., 2025). The novelty of this approach therefore lies in the synthesis of learning through research, the development of higher-order thinking skills, and the creation of an integrated, collaborative and contextual scientific learning ecosystem an area that has been overlooked in previous studies. This study aims to analyse the effect of the learning by research model on improving students' critical thinking and analytical skills.

Methods

This study aims to develop a research-based learning model (learning by research) as an innovative approach in Indonesian education, while also evaluating its effectiveness in improving students' critical and analytical thinking skills. Using a research and development method, the model emphasizes scientific thinking processes and the application of scientific methods in learning. It is implemented through co curricular activities, which complement intracurricular learning and play a key role in strengthening student competencies, especially character development.

The model integrates multiple disciplines through mini research projects in natural sciences, social sciences, and applied sciences, encouraging collaboration across subjects such as mathematics, ICT, language, and culture. Through these projects, students develop essential competencies, including critical reasoning, creativity, collaboration, independence, and communication. The outcomes of this approach are student research projects conducted over a year with teacher guidance, which can be submitted to competitions such as the Indonesian Student Research Olympiad (OPSI), thereby fostering both academic skills and a healthy competitive spirit. This study was conducted at State Junior High School 49 Jakarta and State Junior High School 66 Jakarta. The schools were selected using purposive sampling, taking into account those with co-curricular programmes that align with the OPSI programme. The data for this study were obtained from questionnaires measuring critical thinking and analytical thinking. The data were analysed using a manova test (Johnson, 2018).

In developing learning by research, the research model used in this study is the ADDIE model (analyse, design, develop, implementation, and evaluation) (Branch, 2009).

Figure 1. ADDIE models diagrm (SessionLab.com)

Table 1. Description of the stages of the ADDIE model

No.	Stage	Activity
1	Analyze	1. The analysis stage involves conducting interviews and surveys with students, teachers, and school principals regarding the deep learning process implemented at the school. 2. In addition, it also explores information about strategies for achieving graduate profiles from the deep learning process that has been carried out by the school. 3. How schools implement co-curricular activities to support deep learning in schools. 4. This stage also explores information on how schools interpret the deep learning formula that will be applied in learning. 5. In addition, it also identifies problems and obstacles faced by schools in implementing deep learning and its constituent elements.

		6. Furthermore, this study also formulates the co-curricular domain, which is divided into the domains of natural sciences, social sciences, and arts, as well as their interdisciplinary derivatives. 7. It also explores information about the learning syllabus, syllabus guidelines as the basis for co-curricular activity design, and the synchronisation of co-curricular activities to complement intracurricular activities so that graduate profile achievements can be attained.
2	Design	1. At the design stage, a plan for the learning by research stages is developed, referring to the analyse stage. Development of the syntax model for learning by research. The syntax of learning by research describes the scientific thinking process through the stages of the scientific method. 2. Developing a syllabus and tools for co-curricular activities on the development of scientific thinking and scientific attitudes using the learning by research model. 3. Preparing a draft of critical thinking parameters, namely determining the dimensions of critical thinking measurement. 4. Preparing a draft of analytical thinking parameters, namely determining the dimensions of analytical thinking measurement.
3	Develop	1. At the development stage, the design stages of the learning by research model syntax are created in detail with a more contextual description of the themes of science, social studies, and technology. 2. Developing a syllabus and tools for co-curricular activities on the development of scientific thinking and scientific attitudes using the learning by research model. 3. Compiling critical thinking questions by breaking down the dimensions into statements or questions. 4. Compiling questions on analytical thinking by breaking down the dimensions into statements or questions. 5. Conducting an analysis of the questions regarding critical thinking and analytical thinking instruments. 6. Conducting an expert review of the developed learning by research model and revising the results based on the feedback.
4	Implement	During the implementation stage, the learning by research model is applied in co-curricular activities. In the learning by research model, there are syntaxes that are integrated with the content of co-curricular learning materials. In co-curricular activities at school, the focus is on enabling children to conduct independent research, with the main objective being student participation in OPSI activities. Students are taught scientific thinking, scientific attitudes, and scientific methods, and their critical thinking and analytical skills are assessed before and after the treatment. The design for testing critical thinking and analytical skills is as follows (Sugiyono, 2019): O1 x O2 Description: O1: before treatment (critical thinking and analytical skills) X: application of the learning by research model O2: after treatment (critical thinking and analytical skills)
5	Evaluate	Each stage is evaluated

(Source: Branch, 2009)

In research measuring the success of learning by research development, there has been an increase in critical thinking and analytical skills. The learning by research model design is as follows.

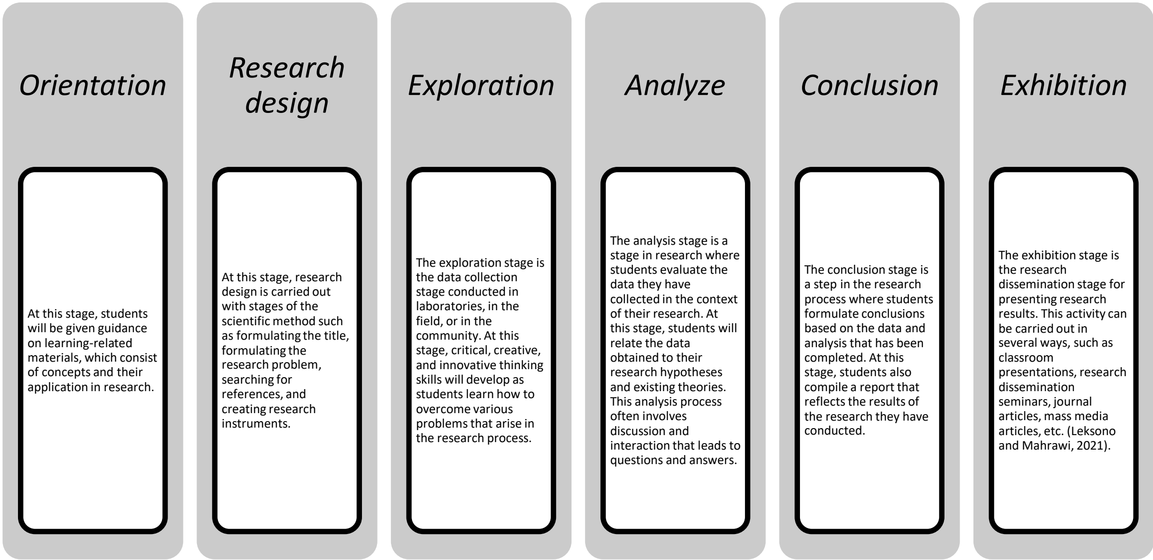

Figure 2. Learning by research models

The co-curricular activities carried out in this study were cross-subject collaborations or science research projects (natural sciences, social sciences, and technology) that culminated in students conducting research for almost a year. In addition, the research conducted or carried out by students was also entered into a national research competition (Indonesian student research olympiad/OPSI) held by the National Achievement Centre, Ministry of Primary and Secondary Education. The learning by research model was implemented at SMP Negeri 49 Jakarta Timur and SMP Negeri 66 Jakarta Selatan (see Figure 3). This research was conducted from January to November 2025. Students were given a pretest with instruments to measure critical thinking and analytical skills, then they participated in co-curricular learning activities held every week. The co-curricular activities were conducted outside of the intraschool curriculum. Students were given research projects to be carried out over a period of approximately one year. In addition to conducting research projects, students were also involved in a research competition called OPSI. During the research project activities, students were provided with content on scientific methods, scientific attitudes, and scientific thinking. Students were also guided in writing research proposals and reports. Each week, in addition to the material, students were also given stimuli in the form of science-based experiments.

(a) (b)

Figure 3. The learning by research model at SMPN 66 Jakarta (a), SMPN 49 Jakarta (b)

In developing the learning by research model, the model developed was tested by experts focusing on the development of learning models and learning instruments. The expert assessment evaluated the learning tools used in learning by research, such as the learning or training syllabus, training materials, and assessments in the learning by research model. An assessment of critical thinking instruments and analytical skills was also carried out. The measure of success in implementing the learning by research model is an increase in students' critical thinking and analytical skills in co-curricular activities. The rubric for measuring critical thinking and analytical skills can be seen in the Table 2.

Table 2. section on assessment of students' critical thinking and analytical skills critical thinking ability

No	Dimension	Question Item
1	Interpretation	1. Explain the meaning of data obtained from observations/experiments. 2. Identify research problems based on observed phenomena. 3. Classify information relevant to the research topic.
2	Analiyze	1. Identify the relationship between variables in the study. 2. Distinguish between facts and opinions in the reference sources used 3. Examine the accuracy of the data before drawing conclusions.
3	Evaluation	1. assess whether the references used are reliable. 2. evaluate whether the research results support the proposed hypothesis. 3. critique the research procedures that have been carried out.
4	Inferention	1. draw conclusions based on the data obtained. 2. formulate hypotheses based on theoretical studies and observed phenomena. 3. predict possible research results based on data patterns.
5	Eksplanation	1. presenting the research results in a coherent and logical manner. 2. explaining the reasoning behind my conclusions.
Analyze ability		
1.	Problem Identification and Clarification	1. Identify research problems based on observed phenomena. 2. Limit the scope of the problem so that the research is more focused. 3. Formulate research questions that are relevant to the topic of study
2.	Grouping and Organising Information	1. Group the research data according to the variables studied. 2. Organise the data in tables or graphs to facilitate analysis. 3. Distinguish between data that is relevant and irrelevant to the research objectives.
3.	Analysis of Inter-Variable Relationships	1. explain the relationship between independent and dependent variables. 2. find patterns or trends in the data obtained. 3. identify factors that influence the research results.
4.	Data Interpretation	1. explain the meaning of the data processing results. 2. relate the research results to relevant theories. 3. explain the differences between the initial and final data results.
5.	Analytical Conclusions	1. Identify research problems based on observed phenomena. 2. Limit the scope of the problem so that the research is more focused. 3. Formulate research questions that are relevant to the topic of study

(Source: Facione, 2011)

The instruments that have been developed will then undergo validity and reliability testing. The validity tested is construct validity and the CVR (content validity ratio) method, which assesses the validity of critical thinking and analysis instruments. Reliability testing is carried out by calculating Cronbach's alpha.

The data obtained after pre-test and post-test assessments of critical thinking and analytical skills were then statistically analysed. Statistical tests conducted included normality, homogeneity, and manova tests to measure the impact of the learning by research model on critical thinking and analytical skills.

Results and Discussion

This study focuses on the development of a learning by research model and its implementation. This model integrates the scientific method with the process of knowledge construction, functioning as a mini-research project. It can be integrated into both curricular and co-curricular learning. The learning by research model developed is implemented in co-curricular activities, which are activities that involve cross-disciplinary fields that support intracurricular learning. Learning by applying scientific methods (learning by research) can shape students' thinking patterns to be more scientific, thereby supporting students' thinking patterns in classroom learning. Students with good thinking patterns will have critical and analytical thinking skills, which are part of the profile of deep learning graduates. In addition to CTS, the learning by research model can also support other deep learning graduate profiles. However, this study focuses on critical thinking and analytical skills.

The current curriculum, which implements deep learning, formulates graduate profiles such as critical reasoning (which includes analytical skills), creativity, collaboration, independence, and communication (Ministry of Education and Culture, 2025). The five pillars of the deep learning graduate profile can be realised by forming a scientific mindset based on research. Although this study focuses on measuring critical reasoning parameters, which include critical thinking and analytical skills, the learning by research model can also indirectly foster creativity, collaboration, independence, and communication within the syntax built into the model. The following is a synchronisation between the stages of learning by research and the deep learning graduate profile (Figure 4).

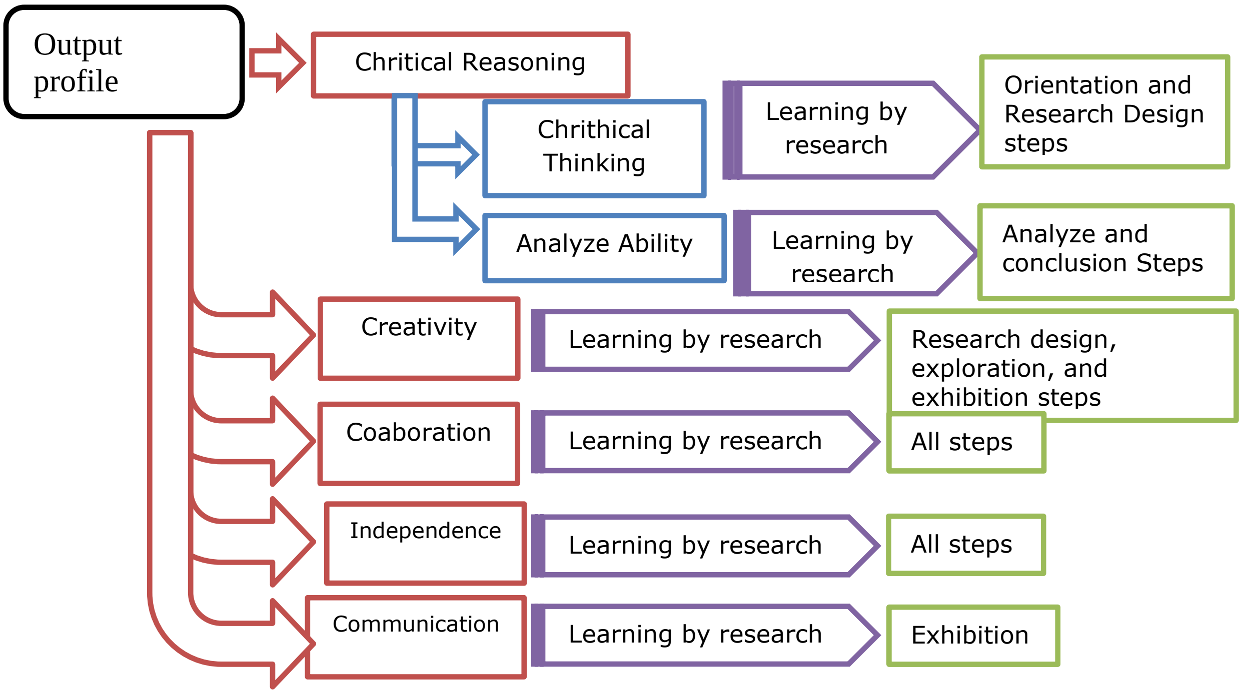

Figure 4. Synchronisation of deep learning graduate profiles with steps from the learning by research model.

The learning by research model was developed using the ADDIE model. The ADDIE model consists of the stages of analyse, design, develop, implement, and evaluate. The first stage is the analyse stage, which involves analysing the needs of students, teachers, and schools. It also explores the activities of in-depth learning and student co-curricular activities.

Analyze Stage

The analysis stage was conducted through interviews and surveys with students, teachers, and school principals. The data obtained related to the in-depth learning process, strategies for achieving graduate profiles, and co-curricular activities. The following are the results of interviews and surveys with students, teachers, and school principals.

Table 3. Survey results and deep learning interviews

Component	Student	Teacher and Principal
Deep learning process	Learning at school during the *merdeka* curriculum period and in-depth learning is slightly different, with more projects, although the *merdeka* curriculum also includes P5 projects.	Deep learning is a learning process oriented towards meaningful mastery of concepts, enabling students to transfer knowledge to new contexts. Although there is still a transition period from the *merdeka* curriculum to a curriculum with deep learning, deep learning includes co-curricular activities that are not found in the *merdeka* curriculum.
Strategy for achieving graduate profiles	-	To achieve the desired graduate profile, the school has taken several strategic steps, such as forming learning communities to evaluate and reflect on learning activities that have been carried out. In addition, it also maximises co-curricular and extra-curricular activities to support classroom learning. In practice, co-curricular activities take the form of numeracy literacy projects and science projects, such as making eco-enzymes, to implement cross-disciplinary activities.
Co-curricular activities	There are cultural projects such as cultural performances, ecoenzyme production, and language and numeracy projects.	Activities carried out in implementing co-curricular programmes to integrate cross-disciplinary fields such as language and culture month, numeracy literacy, ecoenzyme production and ecobrick making.
Problems and obstacles in deep learning	-	Deep learning is an excellent breakthrough in shaping students' knowledge and character. The activities carried out in deep learning are also very different from the previous curriculum. The material is more enriched and supported by digitalisation from the government. In addition, the co-curricular activities in deep learning are an excellent programme for shaping students' character and mindset, and broadening their horizons when these co-curricular activities involve cross-disciplinary subjects. However, the implementation of deep learning in connection with co-curricular activities is not yet clearly visible. There must be a connection between the achievement of the deep learning graduate profile and intracurricular and co-curricular activities in order to achieve the graduate profile. The co-curricular programmes that have been implemented are expected to support cross-disciplinary and intra-curricular studies. Therefore, a co-curricular programme is needed that can be synchronised with intra-curricular activities and can shape students' character and mindset in depth.

From the results of the needs analysis in the analyse stage, it can be concluded that deep learning is a new breakthrough and also something that is very useful in shaping students' thinking patterns and character. Deep learning activities include intracurricular, cocurricular, and extracurricular activities. In optimising co-curricular activities, a programme is needed that is synchronised with intracurricular activities and can achieve the deep learning graduate profile (PM). Therefore, a programme that optimises co-curricular activities is needed. Based on the results of the needs analysis, the development of a learning model or programme to optimise co-curricular activities is the learning by research model. The learning by research model is an innovation in learning where this programme offers the formation of students' character and mindset by combining critical thinking and analytical skills.

Design Stage

At the design stage, formulate derivative profiles from critical reasoning (critical thinking and analytical skills, creativity, collaboration, independence, and communication). In addition, plan synchronisation steps between deep learning outputs profiles. The learning by research model developed is capable of building students' scientific attitudes and ways of thinking. Students who have good scientific thinking skills will correlate with critical thinking and analytical skills. In this study, the learning by research model was applied in co-curricular learning, which was conducted outside of core lesson hours. The activities involved exposing students to research materials and simple procedural experiments so that they could understand the meaning of research. The development design of the learning by research model is as follows.

Orientation

- This stage involves providing learning stimuli, stimulating students with simple concepts, which must be understood that at this stage the teacher or trainer does not explain the reactions or processes in depth. This is because students have already learned the material in class. The teacher only explains the material and its relevance in nature in simple terms, as well as how the theory is proven. At this stage, students are also taught how to use journals in research related to the research or experiments to be conducted. Journal information can be accessed through websites such as Google Scholar and ScienceDirect. In addition, students are also allowed to use journal search engines such as Consensus and Perplexity.

Research Design

- At this stage, students are invited to discuss in groups to determine the experiments or research they want to conduct. Students in each group determine the methods they want to use, the tools and materials, and the work procedures. In addition, students also create worksheets and research or experiment parameters to be measured. At this stage, students are allowed to surf the internet or use A

Exploration

- In the exploration stage, students conduct experiments or experimental stages to prove established theories or hypotheses. At this stage, referring to the established research design, the steps to be taken are based on the worksheet that has been prepared. When students obtain results that do not match the theory, they can try repeating the experiment to obtain consistent results. At this stage, scientific thinking skills are formed and students' scientific attitudes are well honed.

Analyze

- Analytical skills will be developed at this stage. Students will review the data obtained from experiments and research in groups. If the research requires statistical testing, the teacher will assist students in conducting statistical testing, either manually or using SPSS tools. The results of the experiments or research will be proofread against existing theories to determine whether they are consistent with the theories. At this stage, students can also verify and analyse data with the help of AI or other online tools. In research that produces a product, the data obtained comes from expert testing and product trials, which will also be analysed.

Conclusion

- At this stage, students make inferences from the data they have obtained, what the essence of the research or experiment they have conducted is, and understand the core of the research by drawing conclusions.

Exhibiton

- The results of experiments and research conducted by students can be published in several ways. These include writing research or experiment reports, writing scientific articles in the form of journals or proceedings, giving scientific presentations in class, and other methods such as research result examinations.

Figure 5. Stages of learning by research in co-curricular learning

In the learning by research model, students can be facilitated in conducting simple experiments over several weeks or undertaking long-term research over one semester or one year. Learning by research, as applied in co-curricular learning, integrates several interdisciplinary fields into a series of research projects. Co-curricular activities that apply the learning by research model not only instil the values of research, scientific attitudes and scientific thinking, but also enable schools to achieve their target of developing students' critical reasoning and analytical skills and making them competitive, so that their research can be entered into the OPSI. The research fields are in the areas of natural sciences (IPA), social sciences (IPS), and applied sciences (IPT). The following is the synchronisation between co-curricular activities and the learning by research model.

Table 4. Synchronisation of learning by research with cross-subjects

	Research Cluster	Supporting Subjects	Examples of Research Titles
Learning by Research Model	Natural Science (IPA)	IPA, Mattematic, Languange,	1. Analysis of Green Bean Growth Rate through Simple Linear Mathematical Modelling 2. Utilisation of Cocofibre as an Environmentally Friendly Growing Medium to Enhance Mustard Plant Growth (*Brassica juncea*)
	Social Sciences (IPS)	IPS, Cultural and art, Civic, Religion, Mathematic, dan Languange	1. Intercorrelation between parenting patterns, social interaction, and financial literacy on students' online gambling behaviour 2. Development of an e-museum to preserve Betawi culture from the perspective of art appreciation and student interest
	Applied Science (IPT)	Natural Sciences, Social Sciences, Arts and Culture, Civic Education, Religious Education, Mathematics, and Languages, KA Coding, Information Technology, and Physical Education	1. Development of hydroponics integrated with IoT to improve crop quality 2. Design of a simple water filter using local materials to raise health and environmental awareness among communities around schools

Development Stage

At the development stage, the syntax design of the learning by research model that has been developed is described in detail. The syntax plan at the design stage is explained in more detail and linked to the co-curricular activities that will be carried out. In addition, at this stage, there is an assessment by learning model development experts to provide feedback for improving the learning by research model in the future. The following is a description of the learning by research stages and their synchronisation with deep learning.

Table 5. Stages of learning by research in co-curricular learning short/shortcourses (deep learning)

Syntahx Learning by Research	Activity	Output	Profiling	JP (Time)
Orientation	The teacher provides guidance on topics such as photosynthesis. The teacher mentions the materials needed for photosynthesis, which are taken from the air (CO_2) and soil (water and nutrients). The teacher also writes down the reaction equation for photosynthesis: $6CO_2\,(g) + 6H_2O\,(l) \rightarrow$	Students have a basic understanding of photosynthesis.	Critical Thinking, Collaboration, Independence	2 x 50 minutes

	$C_6H_{12}O_6$ (s) $+6O_2$ (g). Derivatives of photosynthesis metabolism. The teacher briefly and simply mentions the benefits of photosynthesis for life. The teacher explains Ingenhouze's experiment on proving photosynthesis, namely with the parameter of detecting oxygen with hydrilla plants. Students are divided into small groups to conduct mini research. The teacher directs students to conduct experiments related to photosynthesis.			
Research Design	In the research design stage, students design a simple experiment on photosynthesis. This includes detailing the necessary tools and materials, independently creating worksheets, establishing experimental procedures, and selecting the desired experiment, such as Sachs' experiment.	Students are able to create simple worksheets in the form of notes, such as logbooks. Students can also identify the tools and materials used and the work procedures involved in the experiment.	Critical Thinking, Creativity, Collaboration, Independence	2 x 50 minutes
Exploration	In the exploration stage, students conducted experiments on photosynthesis, prepared tools and materials, and read worksheets that they had created independently based on the research design stage. In this stage, students conducted Sachs' experiment on photosynthesis. In Sachs' experiment on photosynthesis, students prove that the result of photosynthesis is amylum. Students prepare two leaves from a plant, cover one leaf and leave the other uncovered. Then, students carry out the procedure according to Sachs' experiment.	At this stage, students can conduct experiments according to the planned work procedures. In addition, students record the data obtained, which will later be processed in this experiment. Students are able to write reports on the results of the experiment.	Creativity, Collaboration, Independence	2 x 50 minutes
Analyze	At this stage, students conduct an analysis based on the results of the Sachs test. Students follow the procedures of the Sachs test to prove the presence of amylum. The data results are compared between closed and open leaves. The analysis is also supported by theories that support the experiment. In searching for supporting references, AI tools such as consensus and perplexity are used.	Students are able to critically analyse Sachs' experiment and relate it to existing theories. Students are able to write reports on the results of the experiment.	Critical Thinking, Collaboration, Independence	2 x 50 minutes
Conclusion	At this stage, students make inferences from the data obtained. That plants perform photosynthesis and produce amylum as evidence. Proof through experimentation. The conclusion will illustrate the students' CTS.	Students can draw inferences from data. Students are able to write reports on the results of experiments.	Critical Thinking, Collaboration, Independence	
Exhibition	At this stage, students present the results of simple experiments or research conducted through	Students are able to produce presentation slides of their	Creativity, Collaboration, Independence, Communication	2 x 50 minutes

	scientific speeches in class or other forums.	experiments or research, posters, publications via social media, or publications via scientific articles in journals and proceedings.

In the learning by research model, it can be applied not only in experiments or short-term research (one-time observation). It can also be done through long-term research projects, namely one semester or one academic year. The following is a description of the stages of a long-term research project (research examples taken from the fields of natural sciences, social sciences, and technology).

Table 6. Stages of learning by research in co-curricular course learning and research implementation (deep learning)

Tahapan Learning by Research	Activity	Natural Science (IPA)	Social Science (IPS)	Applied Science (IPT)
Orientation	Educators provide material on research, the benefits of research, and the urgency of research. In addition, educators provide material on the steps of the scientific method, scientific attitudes, and scientific thinking. Educators also explain the clusters or areas of research in the fields of natural sciences, social sciences, and technology (in accordance with the areas of research in OPSI).	Students understand the concepts of research, scientific methods, scientific thinking, and scientific attitudes.	Students understand the concepts of research, scientific methods, scientific thinking, and scientific attitudes.	Students understand the concepts of research, scientific methods, scientific thinking, and scientific attitudes.
Research Design	In the research design stage, students formulate problems, create research titles, determine research variables, create hypotheses (if any), determine the measuring instruments used to obtain data, determine the tools and materials, determine the steps or procedures for the research to be carried out, and prepare logbooks or worksheets.	In science research, students formulate research questions and titles, as well as research variables. The research topic is: 'Analysis of the Growth Rate of Green Beans through Simple Linear Mathematical Modelling'. The research variable is the calculation of the growth rate through mathematical modelling. Students prepare the necessary materials and equipment, such as soil, pots, plant seeds, and measuring tools such as rulers or	In social studies research, students formulate research questions and titles, as well as research variables. The research topic is: 'The development of an e-museum lenong in preserving Betawi culture from the perspective of art appreciation and student interest'. The research variables are the development of an e-museum lenong, art appreciation, and interest. Students prepared the necessary tools	In the field of IPT research, students formulate research questions and titles, as well as research variables. The research topic is: 'Development of hydroponics integrated with IoT in improving crop quality'. The research variables are the calculation of crop quality based on the number of leaves and the height of hydroponic plants, as well as other variables such as IoT-based hydroponics. Students

		measuring tapes. Students also prepare worksheets or logbooks.	and materials, such as art appreciation instruments and art interest instruments. In addition, students also prepared ArtSteps as a tool for creating an e-museum. Students also prepared worksheets and logbooks.	prepare the materials for the hydroponic installation, prepare the integrated IoT hydroponic application, and prepare other measuring instruments such as temperature gauges, humidity gauges, and meters. Students also prepare worksheets or logbooks.
Exploration	At this stage, students carry out work procedures based on worksheets or work steps that have been planned in the research design stage.	At this stage, students carry out seedling cultivation, then measure the height of the plants periodically, while also ensuring that other factors remain under control, such as temperature, soil pH, humidity, plant nutrient concentration, and so on. The data is entered into a logbook or worksheet.	At this stage, students developed a digital e-museum containing material on Lenong and Betawi culture, and conducted expert and user testing. The next step was to measure the effectiveness of the e-museum in schools and gauge students' appreciation and interest in the arts. The data was entered into a logbook or worksheet.	At this stage, students build a hydroponic installation and connect it to a microcontroller in the IoT system. Students can control water pH, temperature, and nutrient content parameters. Data is entered into a logbook or worksheet.
Analyze	At this stage, students conduct analyses based on their research findings. They process the data obtained and may use tools such as SPSS. In analysing and writing their discussions, students may also use AI tools such as consensus and perplexity to connect with existing research articles.	Students processed plant height data and then analysed it using linearity formulas in mathematics.	Students processed data on art appreciation and interest in art, as well as control and experimental class scores. Data processing was also assisted by SPSS.	Students processed data on crop quality improvement, namely the number of leaves and plant height. The data was processed using descriptive statistics.
Conclusion	At this stage, students make inferences from the data they have obtained. Their conclusions will illustrate their CTS.	The students concluded that the growth rate of mung beans showed a linear pattern.	Students concluded that e-museums have an impact on increasing students' appreciation and interest in art.	Siswa menarik Kesimpulan bahwa pengguna IoT dalam system hidroponik meningkatkan mutu hasil tanaman.

Exhibition	At this stage, students present the results of simple research conducted through scientific speeches in class or other forums.	Students publish their research results through research reports, research articles, and posters.	Students publish their research results through research reports, research articles, and posters.	Students publish their research results through research reports, research articles, and posters.

The steps of learning by research that have been described with examples and fields of study as well as outputs have been tested by experts. Are the steps developed appropriate and is learning by research feasible to be developed in accordance with the expertise of experts in the field of model development? The following are the results of the expert assessment.

Table 7. Expert judgement result

Learning by research stage	Expert Judgement	Revision
Orientation	It would be best if the orientation phase were not limited to research alone, but were integrated into the learning process. Could this model not be used in classroom teaching?	Improvements based on expert input indicate that the learning by research approach can be applied in teaching and integrated with classroom material. The orientation stage is not only about how to conduct research and formulate problems, but learning by research can also take the form of presenting material in class, then giving students a case study, and having them conduct research based on a literature review.
Research design	Can students understand research and create research designs?	During several applications of learning by research, students can create their own research designs, albeit simple ones due to their limited knowledge. Even if the research is only a literature study, it is still acceptable because the basis of this model is to build a culture of scientific thinking. In the design or steps of this model, students use AI such as ChatGPT, Consensus, and Perplexity. Therefore, to anticipate this, instructors provide material on various research methods, from simple to experimental.
Exploration	Exploring in various ways is far better than just focusing on field experiments.	At the exploration stage, the search for data should not only focus on experiments; theoretical studies, literature reviews, or case studies may also be options.
Analyze	The ability to analyse data is not easy for junior high school and high school students. It is best to explain how to perform analysis to students who still have basic skills.	The stages in stimulating students' abilities include starting with concrete thinking, using tiered questioning models, applying contextual problems with problem-based learning, analytical thinking structures, visualisation, structured discussions, and feedback.

The results of expert input became one of the recommendations in improving and refining the stages of learning by research. Refining aspects of measurement to how to develop student analysis in more concrete steps was constructive input for the learning by research model. In addition, the choice of methods for exploring data was also important. It is not only limited to experiments, but also includes other options. This is because there is not yet a habit of conducting experiments on students in Indonesia.

Implementation and Evaluation Stage

At this stage, the learning by research model is applied in learning. The parameters for success in learning by research are improvements in students' critical thinking and analytical skills. Students are assessed pre-post on their analytical and critical thinking skills. Has there been an improvement after using the learning by research model? This research was conducted at SMP Negeri 49 Jakarta and SMP Negeri 66 Jakarta in co-curricular classes with a sample of 40 students at each school. The selected students were those involved in the school's co-curricular research projects and in the OPSI competition. The following are the results of critical thinking and analytical skills from both schools (conversion of scores from 0 to 100).

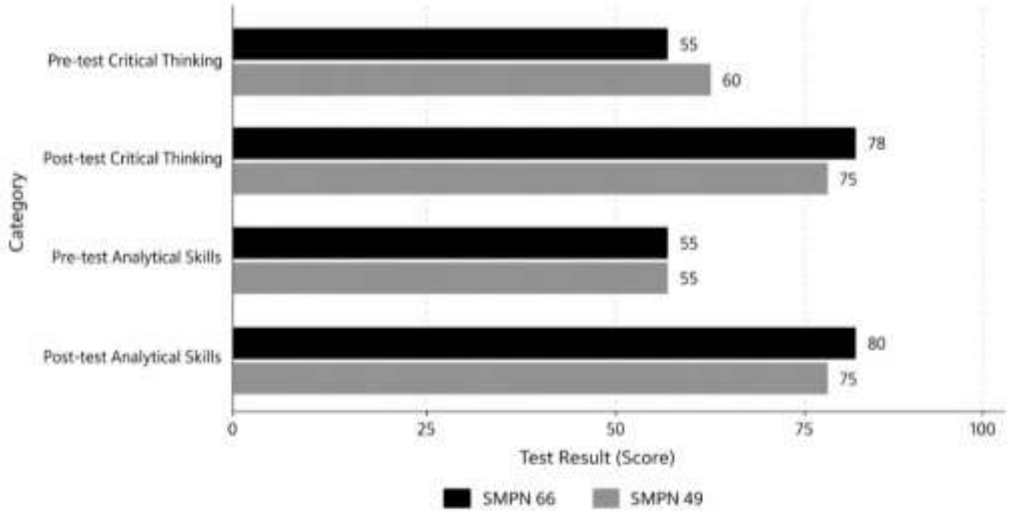

Figure 6. Critical thinking and analytical skills at SMPN 66 and 49 Jakarta

The graph illustrates a comparison of critical thinking and analytical skills among students at SMPN 66 Jakarta and SMPN 49 Jakarta in project-based co-curricular activities. The graph shows four indicators, namely critical thinking pretest, critical thinking posttest, analysis pretest, and analysis posttest with a score range of 0–100. More specifically, in terms of critical thinking, both schools showed a clear improvement from the pretest to the posttest. The initial scores (pretest) were in the moderate category, then increased to the high category in the posttest. The data indicate that both schools experienced improvements from pre-test to post-test in critical thinking and analytical skills, suggesting the effectiveness of the implemented instructional intervention. Notably, SMPN 66 consistently demonstrates slightly higher post-test scores compared to SMPN 49, particularly in analytical skills, where the increase is more pronounced. This pattern implies that the learning model may have had a stronger impact on higher order cognitive processes, especially in contexts where inquiry, reasoning, and problem solving are emphasized. Furthermore, the relatively similar pre-test scores between the two groups suggest comparable baseline abilities, strengthening the interpretation that observed gains are attributable to the intervention rather than initial differences.This indicates that after the learning intervention, students were better able to identify problems, analyse arguments, and draw conclusions based on data. This improvement shows that the learning strategies applied were effective in training HOTS.

In terms of analytical skills, the same pattern was observed. The pretest analytical scores were slightly lower than the critical thinking scores, but after the lessons, there was a significant improvement in both schools. The graph even shows that the posttest analytical scores were relatively high, indicating that students were increasingly able to analyse information, connect concepts, and understand cause-and-effect relationships in a more systematic manner. When comparing the two schools, the difference in improvement is not too great, which means that the learning model used has a relatively consistent positive impact. SMPN 49 Jakarta appears to have a slight advantage in the post-test analysis, while SMPN 66 Jakarta shows a stable improvement in both aspects.

Overall, the graph confirms that the implementation of research-based learning in co-curricular activities contributes to improving students' critical thinking and analytical skills. This data supports the assumption that learning that involves investigation, exploration of real problems, and systematic reflection can strengthen HOTS. In the application of learning by research (LBR), two mechanisms are implemented, namely simple experiments in practical work and literature studies, or in the form of research projects carried out over a period of almost one year (optional competition). Children are stimulated to conduct simple research or experiments. According to expert input, data does not have to be obtained from practical work or experiments, but can also be obtained from literature studies. The following are the activities from simple practical work and literature studies, and research assistance at both schools.

Figure 7. Simple practical activities to stimulate students and research projects

The research projects conducted by students focused on the fields of natural sciences, social sciences, and applied science and technology. In the research process for the national research competition, students achieved the distinction of being among the best researchers. The following are the titles of the research projects conducted by students and the titles that won medals in the national research competition (OPSI).

DragonFresh: Smart Colorimetry Food Indicator Berbasis Pigmen Betasianin Kulit Buah Naga (Hylocereus polyrhizus) Untuk Memantau Kesegaran Dan Keamanan Jajanan Kantin Sekolah	PENGEMBANGAN GAME "REALITY MISSION ONLINE" UNTUK MENINGKATKAN PERILAKU PROSOSIAL DAN PENGURANGAN KETERGANTUNGAN KONTEN INSTAN PADA ANAK GENERASI ALPHA	ATM Pengolah Kompos Cepat 24 Jam berbasis RFID Kartu Pelajar untuk Pemanfaatan Sisa Sampah Organik MBG Siswa Sekolah


LAPORAN PENELITIAN OPSI

E-Museum Lenong : Menjelajah Sejarah Lewat Ujung Jari. Transformasi pembelajaran Budaya Berbasis Website Digital Interaktif untak Meningkatkan Minat serta Apresiasi Budaya Lenong pada Siswa SMP Daerah Khusus Ibukota Jakarta

Figure 8. Title of student research project (left) and title of opsi competition winner 2025

Success in winning the OPSI competition can be understood as a logical implication of applying the learning by research approach in the learning process. Through this approach, students are accustomed to independently identifying problems, formulating focused problems, designing research methodologies, systematically collecting and analysing data, and presenting findings in an argumentative and evidence-based manner. These competencies are key components in the assessment of scientific work competitions, so students who are accustomed to a culture of research have academic and methodological advantages.

Learning by research also builds intellectual resilience and depth of thinking, as students do not just memorise concepts, but test and construct knowledge through the process of investigation. This experience enhances critical, analytical, and reflective thinking skills, which are essential in scientific competitions such as the OPSI. In addition, the habit of presenting research results and scientific discussions trains students' confidence and academic communication skills.

Thus, victory in the OPSI competition is not merely an end result, but a manifestation of a systematic and research-based learning process. This success shows that learning by research is effective in shaping a scientific culture in schools and producing competent, creative students who are able to compete in national academic forums.

Research-based learning is a pedagogical approach that places students as active subjects in the process of constructing knowledge through systematic investigation, problem formulation, data collection and analysis, and evidence-based conclusions. Through these stages, students not only receive information but are also trained to test assumptions, evaluate the credibility of sources, identify patterns and relationships between variables, and reflect on findings logically and objectively. This process directly stimulates CTS because students are required to ask relevant questions, consider various alternative solutions, and provide rational justifications for each argument they construct (Liu & Pásztor, 2022).

In the context of analytical skills, research-based learning encourages students to break down complex problems into more structured parts, organize information systematically, and interpret data based on the appropriate conceptual framework. Engagement in the process of data processing and interpretation strengthens students' capacity to distinguish between facts and opinions, recognize cause-and-effect relationships, and construct valid inferences. Additionally, the stages of reflection and discussion of research results allow for concept clarification and improvement of understanding through scientific argumentation (Bayani et. al., 2025).

This approach aligns with the constructivist paradigm, which emphasizes that knowledge is built through direct experience and intellectual interaction with the environment. Authentic research activities create learning conditions that demand the integration of high-level cognitive skills, so that students become accustomed to thinking deeply, systematically, and based on evidence. Therefore, research-based learning not only enhances content mastery but also contributes significantly to strengthening critical and analytical thinking skills as the foundation of 21st-century competencies.

This research aims to analyze the effect of the learning by research model on improving students' CTS and analytical abilities. This approach positions students as young researchers who actively formulate problems, collect data, analyze findings, and conclude results based on empirical evidence. Theoretically, learning by research is believed to be able to develop CTS because students are directly involved in the scientific investigation process. To test the effectiveness of this model, statistical analysis was conducted, including descriptive statistics, normality tests, homogeneity tests, and manova on two dependent variables, namely CTS and analytical abilities. Here is the descriptive statistics, normality test, homogeneity, and manova data from the implementation of learning by research in co-curricular activities.

Table 8. Descriptive statistical results

Variabel	Mean pretest	SD pretest	Mean posttest	SD posttest	Mean gain
Chrithical thinking	62.45	6.82	81.30	5.94	18.85
Analyze Competence	60.10	7.15	83.25	6.10	23.15

The results above show a significant average increase in both variables after the implementation of the learning by research model. The high mean gain increase indicates that research-based learning is effective in improving students' HOTS.

Table 9. Normality Test (Shapiro Willk)

Variable	Statistic W	Sig. (p)	Description
Chrithical thinking	0.972	0.214	Normal
Analysis ability	0.968	0.176	Normal

Table 10. Homogenity test (levene test)

Variable	F	Sig. (p)	Description
Chrithical thinking	1.284	0.262	Homogen
Analysis ability	1.115	0.297	Homogen

The significance value of both variables is greater than 0.05, so the data is normally distributed and meets the assumptions of parametric analysis. A significance value > 0.05 indicates that the variance between groups is homogeneous. Thus, the assumption of homogeneity is met.

Table 11. Manova test

Multivariate test	Value	F	Sig. (p)	Partial eta squared
Wilks' lambda	0.312	38.457	0.000	0.688
Pillai's trace	0.688	38.457	0.000	0.688

A significance value of 0.000 (< 0.05) indicates that simultaneously there is a significant effect of the learning by research model on CTS and analytical ability. The partial eta squared value of 0.688 indicates that the learning model provides a large contribution to the improvement of the two dependent variables (critical thinking and analysis).

Based on the results of descriptive statistical analysis, the implementation of the learning by research model shows a clear increase in students' CTS and analytical abilities. The average pretest score for critical thinking was in the moderate category, then increased significantly in the posttest to reach a high category. The same pattern is also seen in analytical abilities, where the average score after the intervention is higher compared to before the intervention. The relatively large mean gain indicates that the research-based learning intervention contributes positively to the development of students' HOTS. The relatively stable standard deviation between the pretest and posttest also shows that the improvement occurred evenly among most students.

The normality test conducted using the Shapiro-Wilk approach showed that the significance values for both variables were greater than 0.05. This indicates that the data on CTS and analytical abilities are normally distributed. With the normality assumption fulfilled, the use of parametric statistical analysis is valid and can provide accurate results in testing the research hypothesis.

Next, the test for homogeneity of variance using Levene's Test showed that the significance values for both variables were above the 0.05 significance level. This means that the variance between groups can be considered homogeneous or equal. This condition is important because it indicates that the differences in results obtained are not caused by unequal group variability, but rather by the learning treatment applied. The fulfillment of the homogeneity assumption strengthens the validity of the subsequent analysis conducted.

The main hypothesis testing using Multivariate Analysis of Variance (MANOVA) showed significant results simultaneously for both dependent variables. Multivariate significance values less than 0.05 indicate that the learning by research model has a joint effect on students' CTS and analytical abilities. In addition, the large effect size value indicates that the influence of the learning model is considered strong. This means that the improvement that occurs is not only statistically significant but also practically meaningful in the context of learning.

Overall, the results of the statistical analysis prove that research-based learning is effective in improving students' critical thinking and analytical skills. This model provides a learning experience that encourages students to identify problems, process data, evaluate information, and draw evidence-based conclusions. Therefore, learning by research can be recommended as a relevant learning approach for developing high-level thinking competencies and strengthening the scientific culture in schools.

Table 10 also presents the results of the manova test, which was used to determine the effect of the research-based learning model on two dependent variables simultaneously, namely cts and analytical skills. The two multivariate statistics presented, namely Wilks' lambda and Pillai's Trace, show a significance value (Sig.) of 0.000 (< 0.05). This indicates that there is a significant simultaneous difference between the treatment group and the control group regarding the combination of dependent variables tested. In other words, the LBR model has a significant effect on improving students' CTS and analytical skills.

A Wilks' lambda value of 0.312 indicates that the proportion of variance not explained by group differences is relatively small; thus, it can be interpreted that the learning model makes a strong contribution to the variation in the data. The smaller the value of Wilks' lambda, the greater the effect of the treatment on the dependent variable (Hair et al., 2019). Meanwhile, the Pillai's trace value of 0.688 reinforces these findings, as this statistic is known to be more robust to violations of assumptions and indicates the proportion of variance explained by the independent variables relative to the dependent variable (Tabachnick & Fidell, 2019).

The identical F-value in both tests (38.457) with a significance level of 0.000 indicates consistency in the results, showing that the effect of the learning model is statistically highly significant. Furthermore, the partial eta-squared value of 0.688 indicates a large effect size. An eta-squared value above 0.14 is categorised as a large effect, so these results indicate that the research-based learning model makes a very strong contribution to improving critical and analytical thinking skills.

The results of the statistical analysis showed a significant increase in CTS and analytical abilities after the implementation of the learning by research model. Theoretically, this finding can be explained from a constructivist perspective which states that knowledge is actively constructed by individuals through interaction with the environment and direct experience. In research-based learning, students do not act as passive recipients of information but as researchers involved in the process of formulating problems, developing hypotheses, collecting data, and drawing conclusions. This activity encourages deep cognitive elaboration, thereby enhancing the quality of conceptual understanding (Tanjung et al., 2023).

The improvement in CTS demonstrated by the manova test results is consistent with critical thinking theory, which emphasizes the ability to evaluate arguments, identify assumptions, and make evidence-based decisions. Conceptually, critical thinking is part of HOTS that are at the analysis, evaluation, and creation levels in the revised Bloom's taxonomy. Learning by research provides an authentic context for students to test the validity of information and construct scientific arguments, thereby systematically strengthening the evaluative and reflective dimensions in the thinking process (Darminto et al., 2025). Meanwhile, the improvement of analytical skills can be explained through information processing theory, which states that effective learning occurs when individuals are able to organize, integrate, and interpret information systematically. In the research process, students are required to break down complex problems into simpler parts, identify cause-and-effect relationships, and formulate logical inferences based on empirical data. This process directly trains analytical skills because students are confronted with real data that must be interpreted rationally (Burns et al., 2025).

The learning by research (LBR) model is a learning approach that places research activities at the heart of the learning process, enabling students to actively construct knowledge through scientific investigation. In this context, students are trained to identify problems, collect and analyse data, and draw evidence-based conclusions. This approach has been shown to enhance analytical skills as students are directly involved in the systematic and in depth processing of information. Recent research indicates that research and inquiry based learning can significantly enhance analytical skills through data interpretation and the resolution of complex problems (Zhang et al., 2022; Xu & Shi, 2023).

Furthermore, LBR model also contributes to the development of CTS. The research process encourages students to evaluate information, test the validity of arguments, and make rational decisions based on empirical evidence. Activities such as formulating hypotheses, analysing experimental results, and engaging in scientific discussion strengthen the reflective and evaluative skills that lie at the heart of critical thinking. Recent studies indicate that the integration of research-based learning in higher education consistently enhances students’ CTS, particularly when supported by a collaborative learning environment centred on authentic problems (Rahmatika et al., 2023; Huang & Hew, 2023). Simultaneously, the LBR model exerts a significant influence on analytical and CTS as two interrelated dependent variables. From a cognitive perspective, analytical skills are a key component of critical thinking; consequently, the development of both occurs in an integrated manner through comprehensive scientific activities. The results of multivariate analyses in various recent studies indicate that a research-based approach not only has a partial impact but also collectively strengthens both abilities through the processes of scientific exploration, interpretation, evaluation, and communication (Hidayat et al., 2022; Hair et al., 2021).

The fulfillment of normality and homogeneity assumptions in statistical analysis also supports the validity of the conclusion that the observed improvement is not a coincidence or a result of uncontrolled data variability. The multivariate significance obtained indicates that the learning by research model has a simultaneous effect on two main cognitive aspects, namely critical thinking and analysis. This strengthens the theoretical foundation that research-based learning is integrative and capable of developing various cognitive dimensions simultaneously. Furthermore, from the perspective of 21st-century learning, critical and analytical thinking skills are essential competencies needed to face the complexity of information and global challenges. Learning by research provides authentic learning experiences that simulate real scientific practice, so students not only understand concepts but also internalize the process of scientific thinking. Thus, statistical results showing significant improvements can be understood as a logical consequence of implementing learning strategies oriented towards investigation, reflection, and evidence-based argumentation.

Conclusion

Based on the results of descriptive and inferential statistical analysis, it can be concluded that the implementation of the learning by research model has a significant effect on improving students' CTS and analytical abilities. This finding indicates that research-based learning not only impacts one cognitive aspect but simultaneously strengthens students' critical and analytical thinking dimensions. This improvement reflects the effectiveness of a learning approach that positions students as active subjects in the process of scientific investigation, data processing, and the development of evidence-based arguments. Thus, it can be affirmed that learning by research is an effective learning model in developing HOTS. The implementation of this model is relevant to be applied in an educational context that is oriented towards strengthening scientific literacy, research culture, and 21st-century competencies.

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