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The Effect of Dynamic Problem-Solving Learning Strategy on Students' Critical Thinking Skills

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to examine the effect of dynamic problem-solving learning strategies on students' critical thinking skills. This research employed a quantitative approach with a true experimental design in the form of a posttest-only control group design. The population of this study was drawn from all first-year undergraduate students in the academic year 2022/2023 of the Physics department in the Faculty of Mathematics and Natural Sciences at Universitas Negeri Makassar. The sample was determined using simple random sampling, resulting in 25 students in the experimental group and 27 students in the control group. Based on the data analysis, it was found that the implementation of dynamic problem-solving learning strategies was well-executed and highly rated in terms of management, according to expert judgement. Meanwhile, the analysis results of the critical thinking skills of students in the experimental group were 80.10 in average and

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59.81 in the control group. The analysis of the impact of physics learning strategies on students' critical thinking skills yielded a value of 0.00, which is smaller than 0.05. Therefore, it can be concluded that dynamic problem-solving learning strategies have a significant impact on students' critical thinking skills.

Keywords: Learning strategy; critical thinking; high order thinking skill.

1. INTRODUCTION

The 21st century is characterized by intense competition in various fields of life, including education, especially science education. Our country is faced with the demand for the importance of quality human resources that are able to compete. The quality of human resources is of course the impact of the quality of science education itself, which will be the main force to deal with the problems faced. So we realize that one way to deal with the competition is through improving the quality of education. Education is the basic capital in shaping mindset and intellectual development as well as a means of transmitting values, ideas, and refining ways of thinking. Nowadays, the competition for a decent life depends on creativity and the ability to innovate. According to Law No. 20, Year 2003. Article 3 states that national education functions to develop the potential of students to be capable, creative, and knowledgeable. Improving the quality of education is still being pursued, especially in terms of the development of science and technology and in developing reasoning power, logical, systematic, and critical thinking. The focus of this improvement is based on one of the competencies demanded by the 21st century generation, namely to improve the ability to think at a high level or High Order Thinking Skill (HOTS) or critical thinking skills.

Critical thinking is seen as cognitive skills in interpreting, analysing, evaluating, inferring, explaining, and self-control (Bailin et al., 1999). Burden and Byrd [1] categorises critical thinking as a higher-order thinking activity that requires cognitive skills, which is also justified by Borich [2] that critical thinking requires cognitive skills [3]. Students need to develop science process skills to be able to construct and solve problems and think critically [4]. It can happen because the components of critical thinking are mostly components of science process skills, namely designing experiments, testing hypothesis, hypothesising, predicting, infering, classifying, measuring, observing, and analysing [5]. It can be concluded that if students' science process skills develop, then their critical thinking skills will also develop. Learning to improve science process skills in the form of learning with a scientific / scientific approach that adopts the scientific method, which we all know the educational paradigm in the 2013 curriculum has changed towards a scientific approach that previously used a textual approach. The description provides an overview of the importance of critical thinking skills.

We have all realised the importance of critical thinking. The Secretary Commission on Achieving Necessary Skills (SCANS) revealed that one of the skills that students need to have is thinking skills. The World Economic Forum identified that one of the competencies that students must have is the ability to think critically and creatively [6]. Similarly, the Partnership for 21st Century in 2008 in 21st Century Skills, Eduacation, & Competitiveness explained that the 21st century competency framework is not only limited to having subject matter knowledge, but must be equipped with innovation, communication, collaboration, and critical thinking skills.

The importance of critical thinking skills has been recognised by all parties in Indonesia. The integration of higher order thinking aspects in National Examination questions has been carried out in recent years. It cannot be denied that higher-order thinking, which includes critical thinking skills, is a skill that students are expected to have that educators, especially for universities, are expected to build this skill. Hager and Kaye [7], people who have critical thinking skills have the advantages of: (1) competing effectively in education, work, and achievement in society; (2) critical thinking is the initial need to be a good citizen; (3) thinking to be able to contribute to others psychologically; (4) critical thinking is needed in order to work effectively; (5) thinking is the basis of a person's humanity, and if he cannot develop his thinking ability, his humanity cannot be expressed properly.

Critical thinking is described by Ennis [8] is reasoned and reflective thinking that emphasises making decisions about what to believe and what to do. According to Beyer [9], critical thinking is the ability to judge whether information is valid or not, to distinguish the relevance of information, to distinguish between facts and opinions, and to identify biases and points of view. Most experts assume that critical thinking skills can only be developed through specific subjects [10], one of which is physics. The same thing was expressed by [11], who think that students cannot develop their thinking skills if there is nothing to think about or material to think about (ten Dam and Volman, 2004). On the other hand, physics offers all aspects that can be used by students as a vehicle for thinking.

Physics as a vehicle to foster critical thinking skills is difficult to realise without an educator as a facilitator. If an educator uses the right instructional methods and curriculum materials, students will be able to improve their critical thinking skills [12]. According to [13], that there have been many studies documenting how the development of critical thinking can be improved through the use of specific teaching methods and strategies. McKeachie [14] assumed that critical thinking skills would be difficult to develop in a class with many students [15]. This shows that fostering critical thinking skills is a big challenge for educators in Indonesia, which has a large number of students.

Improving the quality of education in Indonesia, especially critical thinking skills, is carried out continuously and until now continues to be implemented. Various efforts have been taken by the government in an effort to improve the quality of education, one of which is improving the quality of educators as the most important component through certification programmes. One of the main professional abilities and skills that must be possessed by educators is the ability in the field of education and teaching, especially related to learning strategies. Romiszowski (1981), a learning strategy is a generalised view of a course of action adapted from selected commands for learning methods.

Facione [16] stated that the essence of critical thinking is a detailed description of several characteristics, such as the processes of interpretation, analysis, evaluation, inference, explanation, and self-regulation. There are several general characteristics of critical thinking, including the ability to make and evaluate conclusions logically and systematically through examination of problems, evidence, and solutions. However, factually, it shows that the average critical thinking skills of students are still low. The results of initial observations and empirical data by the researcher as a lecturer in the Physics Department, show that early level physics students tend not to understand the concept of critical thinking. They have difficulty applying physics knowledge and concepts in analysing problems. Lack of practice in scientific problems, limited learning resources, biased perceptions, and learning time restrictions contribute to the low critical thinking skills of students. Students are also accustomed to memorising since high school until they enter college, only mastering a few concepts, and lacking training in critical thinking. Difficulties in solving problems and finding alternative solutions are also caused by a lack of basic knowledge. Therefore, the learning process should include essential critical thinking skills, where students should be able to interpret, analyse, evaluate, infer, explain, and self-regulate to find alternative solutions and make decisions. Learning experiences that involve activities that exercise critical thinking skills can significantly influence the development of these skills. The results of these observations are reasonable, because of the results of the research by Haris, et. al (2023) that the critical thinking skills of students in solving high school physics problems as much as 75.50% of the total population are in the low category. The same results were also revealed from research Khaeruddin [3] that the critical thinking skills of students in several high schools in Makassar City are in the low category. Lecturers as educators need to identify effective strategies so that students can practice and improve their critical thinking skills. The use of learning tools and resources that support the achievement of this goal is important to overcome the problems and complexity of knowledge faced by students.

Regarding learning strategies, coherent problem-solving strategies are rarely found in the solutions provided to students, especially in the student solution manuals that usually accompany textbooks. Generally, problem-solving strategies in standard textbooks encourage the use of formula-based schemes such as those compiled in formula summaries at the end of each chapter of the text, and these strategies seem to be commonly used even in classroom teaching. As a result, students simply mimic the way of problem solving in the textbooks. From various unstructured interviews that have been conducted several times, it is known that students admit to a lack of reasoning skills, namely associating ways to solve problems by analogising them with other similar problems. This is not surprising, considering that students only copy the solution method in the textbook that is not related to the problem to be solved (analogue ability).

The demand for teachers, especially physics, is to use effective learning strategies that can shorten the time in improving intuitive conceptual reasoning skills and improving quantitative reasoning. In addition, physics teaching strategies that direct students to engage in mathematical and conceptual reasoning activities are still lacking. If students' mathematical and conceptual reasoning are exercised, then they also get the necessary training in their computational skills, while learning how to use mathematical formulae to derive physics equations. In other words, students can improve their higher-order thinking skills through mathematical understanding of physics problems, which in turn involves "meaningful" learning that goes beyond rote procedures. Moreover, by using quantitative problems that require students to illustrate their conceptual knowledge and understanding, they will show their learning outcomes, which is the best form of feedback. Such a learning strategy will provide a platform for students to apply their mathematical skills and discover new non-formal approaches to calculation.

According Paul and Elder [17] in his article "Critical thinking as a citizenship competence: teaching strategies" explains that for the improvement of critical thinking skills in certain domains, critical thinking is usually not strictly defined and is often almost identified with problem-solving or active learning [18]. In relation to problem-solving, Stenberg (1989) proposed a theory of intelligence called the triarchic theory with one of the sub-theories being componential intelligent behaviour. Where there are 3 components of information processing: (a) learning how to do certain things; (b) planning what to do and how to do it; and (c) doing it. People with this type of intelligence generally do well on tests and come out on top. They can evaluate work and also have higher order thinking skills [19]. Stenberg's phrasing is in line with the steps revealed by (Polya, 2014), which reveals that in general the steps of the problem-solving strategy are Understanding the problem, Devising a plan, Carrying out the plan, and Looking back. In this regard, the problem-solving strategy is expected to improve higher order thinking skills.

Neuroscience is a field of science that specialises in the scientific study of the nervous system, especially the human brain. Neuroscience is closely related to higher-order thinking skills with one of its parts being critical thinking. In the process, this skill goes through the stages of emotion regulation, awareness, monitoring the cognition process. The occurrence of high-level thinking processes is the task of the front part of the brain called the prefrontal lobe/prefrontal cortex. This frontal hemisphere is known as the executive control centre or the centre of higher order thinking. It is also where problem-solving efforts take place [20] (Fitri, 2017).

Another Neuroscience perspective that supports how problem solving can improve higher order thinking skills is expressed by Fiore & Schooler who have an interesting view on creative problem solving involving right hemisphere functions. In fact, it has been suggested that insight can be linked to certain cognitive processes that are known to originate in the right hemisphere of the brain (Beeman. M., & Chiarello. C., 1998). The concept originator of “Emotional Inteligence”, Goleman (1994) explains that humans have two hemispheres of the brain. In short, the left brain functions as the thinking brain while the right brain functions as the emotional brain. If the right brain is stimulated so that it becomes intelligent, the left brain will automatically become smarter. According to Damasio (in Fitri, 2017) states that the right brain is needed to make rational decisions. The ability of the brain to feel this emotional brain will guide cognitive in the right direction. The ability of self-regulation in the process of high-level thinking is the work of the right brain that directs the work of the left brain to monitor the problems faced. This process will develop students' thinking skills to find ways to solve the problem. This is where students' high-level thinking skills will be formed. In other words, problem-solving strategies can improve higher order thinking skills.

It has been described that problem-solving strategies can improve higher order thinking skills. As explained by [20] that the problem-solving strategy stage is divided into four, [21]. Schoenfield (1985) in his book “Mathematical Problem Solving” then revealed that problem-solving strategies should be more complex than previously known, and if we expect students to use these strategies then the steps should be described in more detail. Rojas [21] then divided the steps into six stages, namely: (1) Understanding the problem; (2) Providing a qualitative description of the problem; (3) Planning the solution; (4) Implementing the plan; (5) Verifying the internal consistency and coherence of the equations used; (6) Checking and evaluating the solution obtained.

The problem-solving strategy steps described are known as dynamic problem solving strategies. These solution steps provide an integrated and systematic approach using qualitative (steps 1-3) and quantitative (steps 4-6) reasoning. Educators can emphasise one set of steps only, then provide a structured recipe for carrying out the other half of the steps. Providing a qualitative description of the answer to a problem also means providing a solution as a physicist, and not just a meaningless mathematical answer. Educators emphasise that the solution to a problem is a combination of quantitative and qualitative reasoning.

The advantages of dynamic problem solving strategies have also been proven in several studies conducted by the author, namely the dynamic problem solving strategy can foster students' science process skills in the good category (Haris dkk, 2016). In addition, there are also a number of studies that examine problem solving strategies in physics. Research conducted by Alwi (2017) who applied dynamic problem solving strategies (DPSS) to senior high school students. The result is that the critical thinking skills of students taught using DPSS are higher than the critical thinking skills of students taught using expository strategies. Other research by Wardani (2016) shows that learning using DPSS can be used as a learning strategy that influences students' creative thinking skills. A study by Jalil, et. al (2016) suggested that the DPSS strategy consists of two main lessons, namely learning designed for students to understand concepts and learning to solve physics problems using worksheets.

Based on the description above, the researcher examines and conducts research related to the effect of dynamic problem solving learning strategies on students' critical thinking skills, so the formulation of the research problem answered in this study is whether there is a significant effect of dynamic problem solving learning strategies on students' critical thinking skills in the Department of Physics Faculty of Math and Science, Universitas Negeri Makassar?

2. METHODS

This research is a quantitative research with experimental method. The research design used in the actual experiment is posttest only control group design as follows:

$$\begin{array}{lll} R & X & 01 \\ R & & 02 \end{array}$$

Description:

X : Treatment in the form of applying the developed strategy
O1: Observation/results of students' critical thinking after learning in the experimental class.
O2: Observation/results of students' critical thinking after learning in the control class.
R: Random
(Fraenkel, J.R., et al., 2012)

Population refers to a group of people, objects, or events. The definition of population also includes a broader entity, consisting of various people, objects, and events, which are then used as a basis for generalisation. Thus, population can be interpreted as a number of groups that are the focus of research, and from this group researchers make generalisations based on the results of the research conducted [22]. So that the intended population in this study are all first-year students in the 2022/2023 academic year in the physics department of the faculty of mathematics and natural sciences, Makassar State University. The method of selecting a sample using simple random sampling, resulting in an experimental class of 25 students and a control class of 27 students [22].

Data collection was carried out by implementing learning using synamic problem solving learning strategies in experimental classes and conventional strategies in control classes. The data obtained include data on the implementation and management of dynamic problem solving strategies and the results of quantitative descriptive analysis of students' critical thinking skills. To support the data collection process, the following instruments were used.

1. Strategy Implementation Observation Sheet. Observations of the lecturer's ability to implement learning to improve students'

critical thinking skills, namely the Implementation Observation Sheet developed strategy. Observations of the implementation of learning for each SAP were observed by two observers consisting of 3 score levels, namely score 1 (not implemented), 2 (partially implemented), and 3 (fully implemented) [23]. Observations were carried out simultaneously from the beginning to the end of the learning activities.

2. Strategy Management Observation Sheet. Observation of learning management is the Strategy Management Observation Sheet in the developed strategy. The learning management carried out in using the developed strategy was observed by two observers consisting of 4 score levels, namely score 1 (not good enough), 2 (good enough), 3 (good), and 4 (very good). Observations were conducted simultaneously from the beginning to the end of the learning activities.
3. Critical Thinking Skills Test. Critical thinking skills test is used to measure critical thinking skills in Physics learning including critical thinking skills.

Data analysis has a crucial role in the scientific method, because through the analysis process, the data can be given meaning and interpretation that is useful in overcoming research problems. Before running the prerequisite test of this research, a trial of the instrument is carried out first in the second grade who have studied the material in question. The number of questions tested as many as 20 items. The purpose of this trial is to assess the feasibility of the instrument as a measuring instrument. Validity is a condition that must be met before the instrument is used. The instrument is declared valid when the calculated R value (product moment) is greater than the R table and the reliability value meets the cronbach alpha riliabel requirements [24]. After performing the prerequisite test calculation, the next step is to perform data analysis to test the hypothesis that has been proposed. This test aims to assess whether there is a significant influence between students who follow the learning strategy of dynamic problem solving with students who follow conventional strategies. Hypothesis testing is conducted using the formula "t test" as described by Arikunto [24].

3. RESULTS

3.1 Data of the Implementation and Management of Dynamic Problem Solving Strategy

The results of implementation (Table 1) and management (Table 2) the effect of dynamic problem solving strategies on critical thinking skills in terms of each aspect and each meeting are as follows:

Table 1. Observation results of dynamic problem solving strategy implementation

Meeting	Aspect				Average	Category
	1	2	3	4		
I	2	2	1,5	2	1,9	T
II	2,5	3	3	3	2,9	TK
III	2,8	3	3	3	2,9	TK

Description: T=Implemented, TS=Partially Implemented, TK=Totally Implemented

Table 2. Observation results of dynamic problem solving strategy management

Meeting	Aspect				Average	Category
	1	2	3	4		
I	2,3	2,3	2	2,5	2,3	B
II	3,3	3	3	4	3,3	AB
III	3,3	3,5	4	3,5	3,6	AB

Description: KB=Less Good, CB=Fairly Good, B=Good, AB=Amat Good

In general, the implementation of the dynamic problem solving strategy stages during the lecture obtained the implementation and management of a good dynamic problem solving strategy. It can be seen in the results of the observer's observation that the implementation of the dynamic problem solving strategy stage is carried out as a whole as designed in RPS and SAP, and is very well managed by lecturers in accordance with RPS and SAP. So it can be stated that the dynamic problem solving strategy is used very well in learning.

3.2 Test Data Prerequisites Instrument Critical Thinking Skills

The results of the validation test related to critical thinking skills instruments as many as 20 questions are shown in Table 3 as follows.

Table 3. Validity results of critical thinking skills test item

Question Number	Sig.	r	Statement
Point_1	0,40	0,04	Valid
Point_2	0,40	0,04	Valid
Point_3	0,52	0,00	Valid
Point_4	0,52	0,00	Valid
Point_5	0,60	0,00	Valid
Point_6	0,69	0,00	Valid
Point_7	0,69	0,00	Valid
Point_8	0,69	0,00	Valid
Point_9	0,40	0,04	Valid
Point_10	0,69	0,00	Valid
Point_11	0,61	0,00	Valid
Point_12	0,69	0,00	Valid
Point_13	0,72	0,00	Valid
Point_14	0,70	0,00	Valid
Point_15	0,72	0,00	Valid
Point_16	0,70	0,00	Valid
Point_17	0,34	0,09	Invalid
Point_18	0,24	0,25	Invalid
Point_19	0,35	0,08	Invalid
Point_20	-0,16	0,45	Invalid

r_{table}=0,380 (n=25)

While the test results of the instrument reliability critical thinking skills of students obtained Cronbach's Alpha value of 0.90 or greater than 0.05, so it is declared reliable. It shows that 90% of the variations of the critical thinking skills test consist of elements that contain truth, and the remaining 10% contain elements of error. Based on the grating of the critical thinking skills test instrument before and after the test, it appears that all aspects or indicators after the test, both theoretically and empirically, are in accordance or represented on the grid before the test. This indicates that all instruments have met the element of logical validity.

The results of validity and reliability are also supported by statements by practitioners and experts that the accuracy of measuring indicators for each item of the critical thinking skills test instrument shows very precise results, very clear language clarity, and excellent graphics. Thus, experts and practitioners recommend that the entire test item (as many as 16 items) of critical thinking skills be used in this study. The suggestions and recommendations mentioned above were carried out at the stage before the use of the instrument by reducing the item about critical thinking skills from 20 items to 16 items by considering the relevance of the item about the indicators of critical thinking, graphicity, complexity of the problem in the problem, and the suitability of the knowledge of students as research subjects.

3.3 Data Analysis Results Description and Inferential of Critical Thinking Skills

The results of descriptive analysis of critical thinking skills of students in the experimental class and control Class respectively obtained the average value of critical thinking skills of experimental class students of 80.10 and control class students of 59.81. While the results of inferential data analysis / different tests on the effect of dynamic problem solving strategies to improve critical thinking skills begins with analyzing the normality of each experimental and control class posttest data. The results of the experimental class posttest data normality test obtained a significant value of 0.10 and the control class posttest data normality test obtained a significant value of 0.08. So that both experimental and constraint class posttest data have significance >0.05 or can be stated as both normally distributed data. Furthermore, different tests were conducted independent sample test on critical thinking skills experimental class and control class. The results of the different tests analyzed obtained a significant value of 0.00 or < 0.05 which means there is a significant difference in the average critical thinking skills of experimental class students by applying a dynamic problem solving strategy compared to the control class without applying a dynamic problem solving strategy. Based on the results of descriptive and inferential analysis of the effectiveness of students 'critical thinking skills, it can be stated that there is a significant influence on the learning strategy of dynamic problem solving on students' critical thinking skills.

4. DISCUSSIONS

4.1 Dynamic Problem Solving Strategies

Problem solving strategies are very important to use to increase awareness and creativity of learners which includes the stages of defining (defining), investigating (investigating), reviewing (reviewing), and retrieval of information through a given problem (processing information concerning the problem) [25,26]. The learning objectives associated with physics problem-solving have many facets. The primary goal is to train students to consistently connect various ideas and concepts, apply their understanding in various situations they encounter, and train learners in problem-solving [27].

It can be concluded that, the general purpose of the problem-solving process is to train learners ' ability to: 1) Connect variations of ideas and concepts integrated by self-consistency; 2) Apply understanding in various situations that will come; 3) train educators in solving problems simply. Results of research on problem-solving strategies that have been developed by a mathematician [20] refers to four stages: 1) understanding the problem; 2) devising a plan; 3) carrying out the plan; 4) looking back. Rojas [28] in his paper entitled On the Teaching and Learning of Physics Problem-Solving explicitly divides the stages of the problem-solving strategy as a dynamic process, so it is known as Dynamic Problem Solving Strategies. A strategy that can improve both the teaching and the learning of physics through dynamic problem-solving strategies. It can be concluded that the dynamic problem solving strategy is one of the strategies used to guide learners ' thinking power in solving physics problems consisting of six stages, namely 1) understanding of the problem; 2) proving the qualitative description of the problem; 3) Planning Solutions; 4) execution of the problem according to plan; 5) verification of consistency and coherence of the equations used; 6) checking and evaluating the solutions that have been obtained. From the explanation above, it is known that the 6 stages of problem-solving strategies indicate that there is a linkage between the stages (unified), a systematic step towards a solution approach to physics problems that focuses on both aspects, both qualitative reasoning (stages 1-3) and quantitative (stages 4-5) (qualitative and quantitative reasoning) [28]. The above step is certainly a simplification of a complex and dynamic process. The above framework is also designed so that learners can become experts (adaptive experts) in problem solving by using conceptual knowledge before applying mathematical equations.

The development of cognitive abilities is related to complex and dynamic mental processes through the mechanism of recalling learned material When learners have been at the cognitive level, it is necessary to develop the power of reason to work on the problems. The problem-solving process belongs to the cognitive development phase of learners. The more often learners work on the problems dynamically, it will form the mindset and memory of the memory of physics concepts stored in the long term [29]. Thus, introducing this strategy to universities and high schools provides an opportunity to encourage and strengthen argumentative thinking and reasoning skills. The process of solving scientific problems requires creative thought, the use of available resources (books, computers, articles, etc.) and personal interaction with peers and colleagues [28].

For the purpose of developing dynamic problem solving strategies, researchers adapted a scientific approach in learning abar 21. Learning that applies a scientific approach is a learning process that is designed in such a way that students actively construct concepts, laws, or principles through a series of stages of activity. These stages include observing, formulating problems, compiling or formulating hypotheses, collecting data with various techniques, analyzing data, drawing conclusions, and communicating concepts, laws, or principles found [30]. The application of scientific approach in this learning focuses on the active role of students in building their knowledge through a series of scientific activities. The steps of the scientific approach are implemented starting from the preliminary stage, core activities, to the conclusion.

The preliminary stage aims to strengthen students ' understanding of the purpose and importance of the material to be taught, thus encouraging the formation of high curiosity. This curiosity is considered as the main capital in the next stage of learning, namely the core activities. Core activities, as a learning experience for learners, is the most widely used time to carry out learning with a scientific approach. In learning planning (RPP), educators design systematic learning activities in accordance with scientific steps. Learners are directed to construct concepts, knowledge, understanding, and skills with the help of educators through the activities of observing, asking, reasoning, trying, and communicating. Although these steps do not have to be implemented sequentially, they can be adapted to the context of the knowledge to be learned [31].

1. Observing is the activity of recognizing an object by using the senses of sight, smell, hearing, taste, and touch. This can be done with or without aids, such as reading, listening, or using other senses, so that students can identify certain problems.
2. Asking is the act of expressing a question about something that one wants to know, whether it is related to a certain object, event or process. Questions can be asked orally or in writing, either in the form of direct questions or hypotheses, helping students in formulating problems and hypotheses. These questions should focus on "why" and "how," encouraging answers through experimentation.
3. Collecting data is the activity of seeking information as material to be analyzed and concluded. This can be done through reading books, conducting field observations, trials, interviews, distributing questionnaires, and other methods. The goal is for students to be able to test hypotheses that have been made before.
4. Associating includes data processing through physical and mental activity with the help of certain tools. This process involves classifying, sorting, counting, dividing, and arranging data in a more informative format. Forms of data processing include tables, graphs, charts, concept maps, calculations, and modeling. Students then analyze the data to compare or determine relationships with existing theories, so that they can conclude.
5. Communicating is the action of students in describing and conveying the findings of the activities of observing, asking, collecting and processing data, and associating. Communication can be oral or written, using diagrams, charts, drawings or other formats, with the help of simple technologies or information and communication technologies.

The steps in the scientific approach can be done in an orderly sequence or not, especially in the initial steps, namely the first and second steps. However, it is recommended that the next steps, especially starting from the third step, be carried out sequentially. The application of these scientific steps aims to provide flexibility to learners in building learning independence and optimizing the potential of intelligence. In this learning process, students are invited to construct their own knowledge, understanding, and skills from the learning activities carried out. Meanwhile, the role of educators is to provide guidance, direction, and reinforcement related to the material learned by learners. The application of dynamic problem solving learning strategies with a scientific approach aims to produce output, namely students, who have good critical thinking skills. This approach is geared towards training students' critical thinking skills, enabling them to become independent learners, and stimulating the development of their intelligence potential through in-depth understanding of concepts.

The scientific approach is a method of approach to learning that involves observation, experimentation, data collection, data analysis, conclusion making, and communicating. It encourages students to develop a deep understanding of concepts and processes. The scientific approach supports the dynamic problem solving strategy by encouraging students to understand the problem in depth, collect data, and apply their knowledge to find solutions. A structured scientific process can be the foundation for effective problem solving. The scientific approach encourages the development of critical thinking skills by asking students to design experiments, analyze data, and evaluate conclusions. This process builds students' ability to question information, make inferences, and develop logical reasoning. Thus, it can be stated that the scientific approach is the right learning approach to implement dynamic problem solving strategies.

Dynamic problem solving strategy involves a flexible and adaptive approach to problem solving. This includes the ability to understand the problem, proving the qualitative description of the problem, planning solutions, executing solutions according to plan, verifying the consistency and coherence of data analysis, and checking the evaluation of solutions continuously. The dynamic problem solving strategy is integrated with the scientific approach through the use of experimental methods to collect evidence in overcoming problems. This process creates a learning environment that allows students to develop dynamic problem-solving skills. Based on the results of Needs Analysis and strategy design results, it found the novelty of the dynamic problem solving strategy compared to the general problem solving strategies and dynamic problem solving that has been seen in Table 4 as follows.

4.2 Critical Thinking Skills

According to Kamus Besar Bahasa Indonesia (KBBI), thinking is using reason to consider and decide something. Thinking can also be interpreted as weighing in memory. While the word critical can mean not easily believe, always trying to find mistakes or errors, as well as sharp in analyzing. Kusnawa in Rifqiyana et al. [32] argues that "critical thinking “in the United States is often considered a synonym of ”thinking skills". There are several key words in understanding critical thinking and its relation to curriculum and teaching and learning. First, the nature of the definition of critical thinking and how it relates to what can be categorized as psychological and philosophical perspectives. Second, several different philosophical differences were identified, which relate to the nature of thinking and thinking skills and need to be expanded upon, considering their implications for learning. Third is the issue of assessment and critical thinking with regard to teaching and curriculum. Critical thinking explains goals, examines assumptions, values values, hidden thoughts, evaluates evidence, completes actions, and assesses conclusions.

Ennis [33] critical thinking is defined as “reasonable, reflective thinking that is focused on deciding what to believe or do”. According to this definition, critical thinking emphasizes reasonable and reflective thinking. This sensible and reflective thinking is used to make decisions. Ennis emphasizes principles and critical reasoning skills that are subject-neutral, i.e. logical principles that are not only applicable to a particular discipline but can be applied universally. Recognition of certain minimum competencies in a discipline is important to be able to apply critical thinking skills to that discipline. The process of critical thinking is deductive, which includes the application of critical thinking principles and skills to specific disciplines.

Basen on Ennis [33] there are 12 indicators of critical thinking ability which are summarized in 5 stages as follows.

1. Basic clarification. This stage is divided into three indicators, namely formulating questions, analyzing arguments, and asking and answering questions.
2. The reasons for a decision (the bases for the decision). This stage is divided into two indicators, namely assessing the credibility of information sources and observing and assessing observation reports.
3. Inference. This stage consists of three indicators making deduction and assessing deduction, making induction and assessing induction, and evaluating.

Table 4. Dynamic problem solving strategy

***Problem Solving* according to John Dewey**	***Problem Solving* according to Polya**	***Dynamic Problem Solving* according to Rojas**	***Dynamic Problem Solving* in this reseacrh**
Formulate the problem! Exploring the problem Formulate hypotheses Collecting and classifying data as hypothesis-proving material Proof of hypothesis Deciding on a solution	Understanding the problem Develop a plan Implementing the plan Test the answers	Understand The Problem Provide a qualitative description of the problem Planning solutions Implementing the plan Verify the internal consistency and cohesion of the equations used Examine and evaluate the solutions obtained	Focus On The Problem Problem Analysis Plan and action Evaluation

4. Further clarification. This stage is divided into two indicators, namely defining and assessing definitions and identifying assumptions.
5. Assumption and integration. This stage is divided into two indicators suspect, and combines.

On the other hand, Facione [16] stated that there are six major critical thinking skills involved in the critical thinking process. These skills are interpretation, analysis, evaluation, inference, explanation and self-regulation. Interpretation is understanding and expressing the meaning or significance of various experiences, situations, data, events, judgments, customs, beliefs, rules, procedures or criteria.

1. Analysis is the identification of intended and actual inferential relationships between statements, questions, concepts, descriptions.
2. Evaluation is to assess the credibility of statements or representations that are reports or descriptions of perceptions, experiences, judgments, opinions and to assess the logical strength of inferential or intended relationships between statements, descriptions, questions or other forms of representation.
3. Inference-identifying and obtaining plausible elements, making conjectures and hypotheses, and inferring consequential consequences from data.
4. Explanation is able to state the results of one's explanation, present one's reasoning in the form of strong arguments.
5. Self-regulation means self-consciously monitoring one's cognitive activities, the elements used in those activities and the results obtained, especially by applying skills in analysis and evaluation to one's own inferential judgment research with a view to questioning, confirming, validating or correcting either one's reasoning or its results.

Critical thinking is a process that relies on, and develops, a variety of skills and personal qualities. Like other forms of activity, it improves with practice and with the right sense of what it entails. Critical thinking involves developing a variety of additional skills such as observation, reasoning, decision making, analysis, judgment, and trust [34].

The overall description of the background of the problems in this study and based on the results of theoretical studies or preliminary studies further formulated a framework for determining the solution to be applied in solving the formulation of the problem. Critical thinking skills involve the ability to organize and analyze information critically and logically. It includes the ability to focus questions, analyze arguments, consider the veracity of sources, create and analyze hypotheses, determine actions, solve problems and take decisions, tendency and uncertainty analysis, and make conclusions. Critical thinking skills can be strengthened through the application of a scientific approach, where students are invited to ask questions, analyze data, and draw conclusions based on evidence. Critical thinking skills are important in dynamic problem solving strategies because they enable students to evaluate the effectiveness of proposed solutions, adjust their strategies, and make informed decisions. Thus, critical thinking skills become crucial in dealing with dynamic problems because they allow adaptation to change and uncertainty. In complex situations, these skills allow deep analysis, careful decision-making, and stimulate creativity. Critical thinking also improves problem-solving independence and effective communication skills. With its critical role, critical thinking skills help individuals and organizations adapt and thrive in a dynamic environment.

Based on the results of Needs Analysis and dynamic problem solving strategy design to improve critical thinking skills, it was found indicators of critical thinking skills of physics students who became the focus of improvement compared to critical thinking skills in general or existing can be seen in Table 5 as follows.

By integrating these three concepts in learning, students can develop a deeper understanding, strong critical thinking skills, and dynamic problem-solving abilities. A holistic approach to learning ensures that students not only understand the facts, but can also apply their knowledge in real-world situations.

Thus, a new dynamic problem-solving learning strategy was developed to enhance students' critical thinking skills through scientific approaches and experimental methods. The form of the strategy in question is presented as in Table 6.

Table 5. Critical thinking skills indocator

According to Facione	According to Ennis	According to Tiruneh	In this research
Interpretation Analysis Evaluation Inference Explanation self-regulation	Basic clarification Provide reasons for a decision Conclude Further clarification Conjecture and integrability	Consider Creating and testing hypotheses Analyze arguments Trend and uncertainty analysis Solve problems and make decisions	Focusing questions Analyze arguments Consider the veracity of the source Create and analyze hypotheses Determine the action Solve problems and make decisions Trend and uncertainty analysis Draw conclusions.

Table 6. Dynamic problem solving strategies & critical thinking skills with scientific approach

Scientific Approach	Dynamic problem solving strategy	Critical thinking skills indicator
Observing	Focusing problem	Focusing questions Analyzing arguments
Questioning	Analysing the problem	Consider the veracity of the source Create and analyze hypotheses
Collecting data and experimenting	Plan and action	Determining action Solve problems and make decisions
Analyzing data communicate	Evaluation	Trend and uncertainty analysis Draw conclusions

The results of the effectiveness of dynamic problem solving learning strategies in physics students showed a fairly effective improvement in every aspect of each meeting. This is influenced by the stages of the strategy itself and the characteristics of the student.

Some potential positive results in the implementation of learning strategies dynamic problem solving:

1. Improving students ' ability to understand and describe problems qualitatively.
2. Improving students ' ability to formulate and solve complex physics problems.
3. Developing collaboration skills, because often students work in groups to solve problems together.
4. Improved ability to formulate solution plans and resolve solutions.
5. Improving students ' ability in data verification and evaluation of implemented solutions.
6. Improvinf critical thinking skills at each stage of learning strategies dynamic problem solving.

The results of the positive effectiveness of the application of dynamic problem solving strategies are in line with the results of research Caliskan, et al. (2010) that learning with problem solving strategies have a positive impact on student problem solving performance.

However, the results of the effectiveness of the above can also be influenced by how well this strategy is taught and applied by lecturers, as well as how involved and committed students are in following learning using the strategy. This is in line with Bolton's (1997) statement that if there is an increase in problem-solving skills in students, it will have implications for the creation of a real contribution to the environment in physics learning. In addition, the results of research Jhonson (2010) states that the characteristics of students who have weaknesses in understanding the problem and mathematical skills, it will be an obstacle in solving a problem. So that regular evaluation and intensive feedback from students can help improve the effectiveness of the application of dynamic problem solving learning strategies.

Critical thinking skills are one of the very important skills developed by students in higher education, especially physics students. Physics students are clearly required to be able to understand complex physical concepts and be able to implement them in real-world situations. Dynamic problem-solving learning strategy is an approach designed to develop students ' critical thinking skills through solving dynamic and complex problems.

To understand the concept of applying dynamic problem-solving learning strategies, it is important to first understand what critical thinking is and how it relates to physics. Critical thinking is the ability to actively analyze, interpret, and evaluate information to make informed decisions. In the context of physics, critical thinking involves a deep understanding of physical concepts, the ability to identify problems, and the ability to develop appropriate solutions. This is in line with the results of Sale's (2011) research that dynamic simulations can be an effective learning tool for developing various types of critical thinking skills.

One form of dynamic simulation is a form of experiment designed by students themselves, so students tend to practice developing various types of critical thinking skills to formulate a form of expression. In line with the results of the research of Dakabesi, et al (2019) that learners who are taught using Problem-Based Learning have better critical thinking skills than learners who are taught by conventional methods.

Dynamic problem-solving learning strategy is an approach that aims to develop critical thinking skills by presenting challenging and dynamic problems to students. In this strategy, students are not only taught theoretical physics, but also invited to apply it in situations similar to the real world. Basically, students must learn how to think critically through solving real physics problems. According to Rojas [28], a well-structured problem-solving strategy taught as a dynamic process offers an enabling way for students to learn physics quantitatively and conceptually, while helping students achieve a highly skilled level of innovation and efficiency in the process of teaching and learning physics effectively.

The application of dynamic problem-solving strategy in physics learning through this research has several significant benefits. First, this strategy can help students develop a deeper understanding of physics concepts because they must apply that knowledge in a real context. It also improves students' problem solving skills, which is a very important skill in Physics for everyday life. Second, this strategy allows students to develop critical thinking skills. Facing complex and dynamic problems, students must identify relevant information, formulate a solution plan, and test their proposed solutions. It helps students become more critical and analytical thinkers. As Yazidi (2023) states that developing critical thinking skills can lead to better decision making in various aspects of life. Critical thinking allows individuals to make informed decisions based on sound thinking and strong evidence. It also helps individuals identify and evaluate different options before deciding, which ultimately results in better results.

Although the dynamic problem-solving learning strategy has many benefits, there are also some challenges and obstacles that have been overcome through this study. One is that dynamic problem solving takes longer than traditional teaching methods. This is a challenge for lecturers who must cover more material in the curriculum. In line with the statement Rojas [21] that there are 3 (three) main problems in learning physics, namely:

1. The demands of physics lecturers for effective teaching strategies that can explain how much time should be spent teaching intuitive conceptual understanding and how much time should be spent developing students ' quantitative reasoning, as well as how to teach these two aspects holistically;
2. students' need for appropriate textbooks and worksheets will help them develop physics skills, which are essential to enhance their knowledge of conceptual physics; and
3. Deficiencies in physics learning that result in students not being taught consistent physics problem solving strategies that would allow them to engage in mathematical and conceptual reasoning alone.
4. These three things have been overcome effectively by applying dynamic problem solving learning strategies.

In addition, there are also students who feel frustrated when facing difficult problems. This is overcome by attaching the principle of reaction to a lecturer to provide adequate support and motivate students. The application of dynamic problem-solving learning strategies in physics learning is an effective approach to develop students ' critical thinking skills. It helps them not only understand physics concepts, but also master very important problem-solving skills.

Although there are challenges that need to be overcome, the benefits are much greater. Thus, this approach can be an integral part of effective physics education. In this discussion, we have seen how the application of dynamic problem-solving learning strategies can contribute to the development of critical thinking skills of physics students. By understanding the basic concepts, research results, benefits, and implementation, it can be concluded that the dynamic problem-solving strategy is effective to improve the critical thinking skills of physics students. While there are still challenges to overcome, with the right support and commitment, this strategy becomes an effective tool for creating physics students who have a deep understanding of the material and strong critical thinking skills.

5. CONCLUSION

The conclusion of the research obtained on the development of dynamic problem solving learning strategies to improve critical thinking skills is that there is an influence of dynamic problem solving learning strategies on the thinking skills of students in the Department of Physics, Faculty of Mathematics and Natural Sciences, Makassar State University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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