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Distance Learning Uses a Conceptual Problem-Solving Approach to Improve Problem-Solving Ability on the Topic of Thermodynamics

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ABSTRACT

Distance learning (DL) is the implementation of learning in which students/students and teachers/lecturers are in different places. The main problem faced by DL is how to manage to learn so that its effectiveness equals or exceeds face-to-face learning. In this research, DL has been developed, whose lecture activities are synchronous and asynchronous with the Conceptual Problem Solving (CPS) approach; the learning stages include opening, topic discussion, problem discussion, presentation, and closing. DL is applied to thermodynamics in basic physics lectures at a university in Padang. This study uses a mixed methods method with an embedded experimental design. The research was conducted on students taking Basic Physics 1 courses in odd semesters 2021-2022 with 40 students. The data collected in this study were the results of the pretest and posttest and the results of interviews with students. Quantitative analysis was carried out by calculating the distribution and tendency of the data, t-test, effect size, and n-gain. At the same time, qualitative analysis is done by reducing the data to conclude. The results showed that the average value of students' problem-solving abilities increased, with N-Gain being in the high category and d-effect size in the strong category. This acquisition and the interviews that have been conducted prove that DL with the CPS approach can improve students' mastery of concepts and problem-solving abilities.

INTRODUCTION

Technological developments at these time impact developments in the world of education. The use of technology in education allows teachers and students to be in different places. Learning that allows students and teachers to interact even though they are in different places is called *distance learning* (DL) (Dilmaç, 2020). In practice, DL can be carried out using the method; of virtual learning (Munawaroh, 2005), using Google classroom (Putri et al., 2019), web-based learning (Nugroho, 2012), e-learning assisted learning (Hariani & Wastuti, 2020; Salehudin, 2020), generative learning (Kosiret et al., 2021), as well as mobile learning (Husna, 2020).

DL implementation can be carried out synchronously, asynchronously, or in combination. DL is synchronous learning where the teacher and students are in different places, but the learning is done in real-time without time lags using the internet (Sulistio, 2021). On the other hand, DL is carried out asynchronously at different times between teachers and students so that learning can be done more flexibly until a predetermined time limit (Shahabadi & Uplane, 2015). In implementing DL, synchronous and asynchronous DL can be combined to empower student involvement in learning and positive feedback provided by the teacher (Rehman & Fatima, 2021). Student involvement in the learning process has a positive relationship, meaning that students who are actively involved in the learning process have good problem-solving skills (Ariandi, 2016).

Literature shows that students also have fewer problem-solving abilities. Regarding concept mastery, the cause of student errors in solving problems is difficulty understanding the problems given and needing help interpreting the information obtained in problem-solving questions. In addition to mastering concepts, students also experience difficulties developing strategies or processes to solve problems (Akbar et al., 2017). One of the student's difficulties in solving thermodynamic problems is the first law of thermodynamics in determining positive and negative signs and not being able to interpret these signs in terms of heat, so students are only able to make a description of the problem without making physics principles, applying principles and solving them with improper mathematical procedures. (D. N. Azizah et al., 2018).

Students' problem-solving abilities can be grouped into two groups: students who are in the expert category and students who are in the novice category. Students with problem-solving skills who are experts can solve problems using good problem-solving stages (Ansori et al., 2021). Students in the expert category can identify variables that influence problem-solving, relate these variables to mathematical procedures and consider the concepts used, and analyze these concepts appropriately (Ringo et al., 2019). On the other hand, students in the novice category tend to only solve problems directly at the mathematical procedure stage if they apply the appropriate concepts (Ansori et al., 2021). Students are expected to be in the expert category in solving problems. One way that can be used to help students be in the expert category in solving problems is by using practice questions with the Conceptual Problem-Solving approach.

Conceptual Problem Solving (CPS) is an approach that can produce solutions to problems with higher quality so that students can be in the expert category in solving problems (Docktor et al., 2015). There are three steps in solving problems using the CPS approach: principle, justification, and plan. The first step is the principle, where students identify physics principles that can be used in solving problems. The second step is justification, where students write a justification for the principles used. The third step is planning; in this step, students will solve problems using the principles.

Based on the literature study that has been carried out, the topic of thermodynamics in physics learning is a topic that is difficult for students to master (Adila et al., 2017). Regarding the concept mastery factor, the cause of students' difficulties in solving problems is difficulty understanding the problems given and being unable to interpret the information obtained. In addition, students also experience difficulties in developing strategies or processes for solving problems (Akbar et al., 2017).

Efforts made in this study to improve students' problem-solving abilities are to develop synchronous and asynchronous DL with the CPS approach. The steps for implementing this DL can be seen in Figure 1.

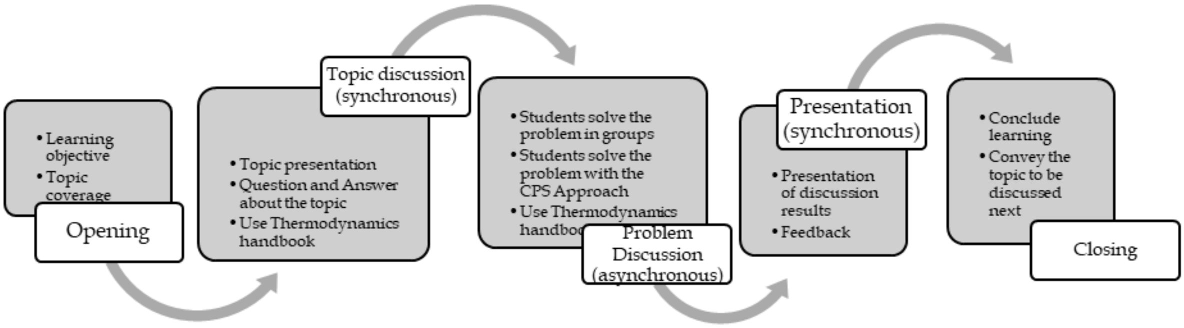


Figure 1. DL Steps with the CPS Approach

Learning using DL that has been developed is carried out for three cycles; each cycle is carried out with the same steps. Five steps in DL have been developed: opening, topic discussion, problem discussion, presentation, and closing. The first stage in this DL is the opening which is carried out for the first 10 minutes to check the readiness of students to start learning. The next stage is the topic discussion. At this stage, the instructor presents the material discussed on thermodynamics, interspersed with questions and answers between the instructor and students to discuss the material being discussed. After carrying out the topic discussion stages synchronously, the instructor then directs the student group to discuss the problems given synchronously using the e-learning that has been prepared, which is also called the problem discussion stage. The problem discussion stage lasts 24 hours, and the instructor monitors student discussion activities. After the first 90 minutes of the problem discussion stage, one of the student groups presented the results of the interim discussion conducted at the presentation stage. After the presentation stage is carried out, the students and instructor conclude the learning that has been carried out (the closing stage) and continue with group discussions to solve the problems given. This study aims to look at the ability to solve problems in thermodynamics using the CPS approach in DL.

METHODS

The method used in this study is a mixed methods research method with an embedded experimental design. Figure 2 is a research procedure using an embedded experimental design.

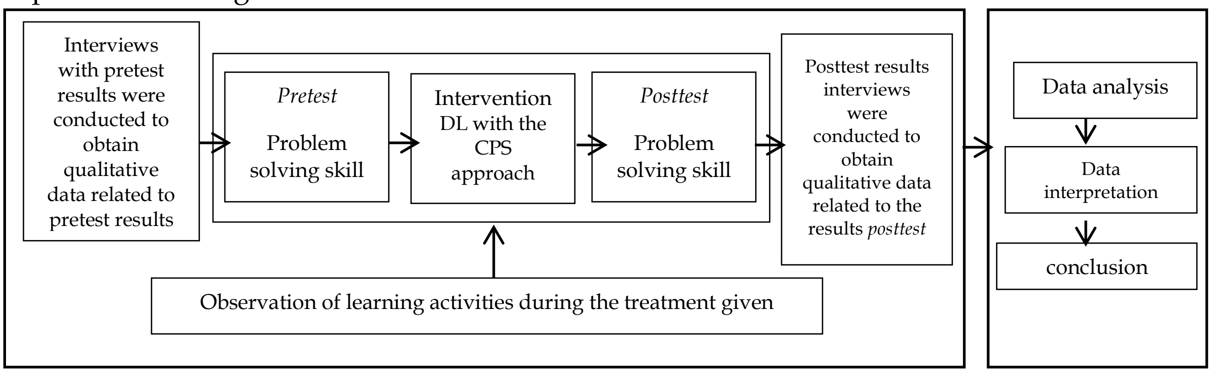


Figure 2. Embedded Experimental Design Research Design

The subjects in this study were Physics Education students from Padang State University who took the Basic Physics I course in the odd semester of 2021. The subjects in this study consisted of 40 students. The types of data in this study are quantitative data and qualitative data. Data were obtained from the pretest and posttest results and interviews conducted. The instrument used in this study was a problem-solving ability test consisting of 2 questions. Instrument indicators can be seen in Table. 1. A physics lecturer has reviewed the instrument. After the indicators consider the items, empirical trials are then carried out, and the results are obtained; the biserial point coefficient is in the interval 0.798 – 0.964, the difficulty level of the questions is in the interval 0.679 – 0.501, the differential power of the items is in the interval 0.798 – 0.964, and the reliability of the items is 0.622.

Table 1. Instrument Indicator of Problem-Solving Ability

Question indicator	Subject matter	Question number
Students can determine the work and heat stress experienced by a gas by analyzing changes in the state of an ideal gas using the equation of state for an ideal gas.	The equation of state for an ideal gas Work on thermodynamic processes The first law of thermodynamics	1
Students can determine the work experienced during one cyclic process cycle, determine the heat absorbed by the gas by applying the first law of thermodynamics, as well the efficiency of the machine in the cyclic process.	The first law of thermodynamics The second law of thermodynamics	2

Data analysis in this study consisted of quantitative and qualitative data analysis. Qualitative data analysis is descriptive statistical analysis consisting of average values, standard deviations, skewness values, and Std. Error. In addition to descriptive statistical analysis, inferential analysis of paired sample t-test, effect size test, and N-gain test was also carried out to see how strong students' problem-solving abilities were. Qualitative data analysis was carried out on the pretest and posttest results, as well as the interviews conducted. Qualitative analysis was done with data reduction, coding, data presentation, and conclusion (Fossey et al., 2012).

RESULTS AND DISCUSSION

Results

Quantitative Analysis of Problem-Solving Ability

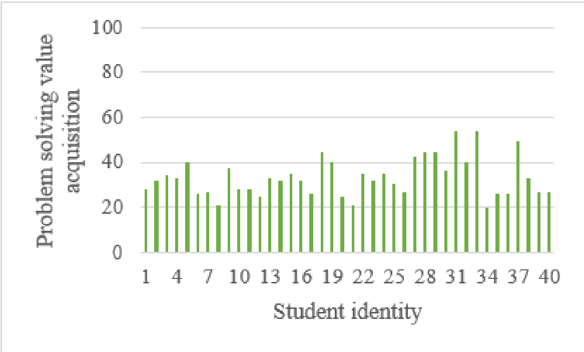
Descriptive statistics in this study provide an overview of the data obtained from this study. Descriptive statistics used to describe students' problem-solving abilities consist of the mean, standard deviation, minimum, maximum, and skewness values. Statistics of student problem-solving abilities are presented in Table 2.

Table 2. Pretest and Posttest Descriptive Statistics of Problem-Solving Ability

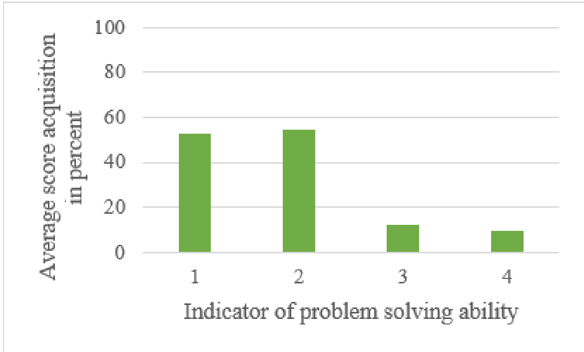
	N	*Mean*	Std. Deviasi	Min	Max	*Skewness*	Std. *Error*
Pretest	40,00	33,32	8,55	20,00	54,00	0,76	0,37
Posttest	40,00	81,57	12,34	60,00	100,00	0,01	0,37

The pretest results of students' problem-solving abilities showed that students' mastery of concepts before being given treatment was relatively low. The average value obtained by students is 33.32. The minimum score obtained by students is 20, and the maximum score obtained by students is 54, achieved by two students. The results obtained for each student are depicted in Fig. 3.1a, and the distribution of the correct answers for each item is shown in Fig. 3.1b.

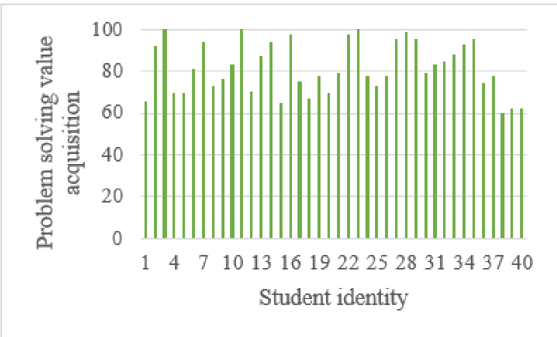
After treatment, post-test results of student problem-solving showed an increase in problem-solving abilities in thermodynamics material. The average score that students can achieve increases to 81.57 from the two questions that have been given. The highest score a student can achieve is 100, but four students still get a score of 60. The results obtained for each student are depicted in Fig. 3.2a, and the distribution of the correct answers for each item is depicted in Fig. 3.2b.



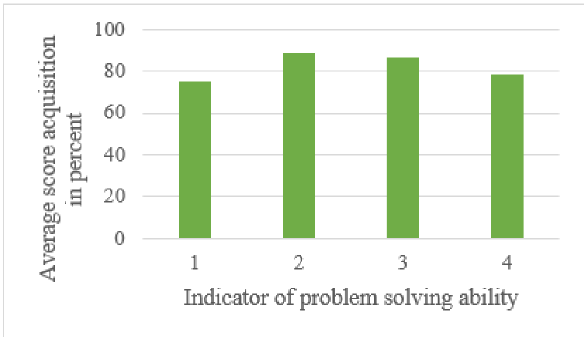
(1a)



(1b)



(2a)



(2b)

Figure 3. Student Problem-Solving Ability
(1a) the score obtained for each student in the pretest
(1b) obtaining correct answers for each question in the pretest
(2a) the score obtained for each student in the posttest
(2b) obtaining correct answers for each question in the posttest

A different test was conducted to see if there was a significant difference between the pretest and posttest problem-solving ability scores. This test uses a parametric statistical test paired sample t-test.

Table 3. Output paired sample t-test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Pre_Test - Post_Test	-48,250	13,898	2,197	-52,695	-43,805	-21,956	39	**0,000**

The results of the analysis are in Table. Three indicates that the significance value of the paired sample t-test is 0.00. Because the significant value obtained was smaller than 0.05, the results showed a significant difference in students' mastery of concepts before and after being given treatment.

Effect size analysis is used to see how much influence DL uses the CPS approach in improving students' problem-solving abilities. The results of calculating the effect size of students' problem-solving abilities in the pretest and posttest were 3.75, which was in the strong category (Cohen et al., 2018).

Once it is known that there are differences in the pretest and posttest scores of students' problem-solving abilities, the next step is to determine the magnitude of the increase in students' problem-solving abilities. The analysis used to determine the magnitude of the increase in student problem-solving skills is by calculating the N-Gain value. The results of the N-Gain analysis of pretest and posttest mastery of concepts obtained an average g value of 0.72 which is in the high category.

Qualitative Analysis of Problem-Solving Ability

Qualitative analysis in this study aims to strengthen the analysis of quantitative data. This study's qualitative analysis of concept mastery aims to explain how students' problem-solving abilities after DL have been carried out using the CPS approach. Qualitative data on students' problem-solving abilities were obtained by analyzing the four indicators of problem-solving abilities on the pretest and posttest problem-solving ability answer sheets. Figure. 4 results from one student's answer in working on problem-solving questions.

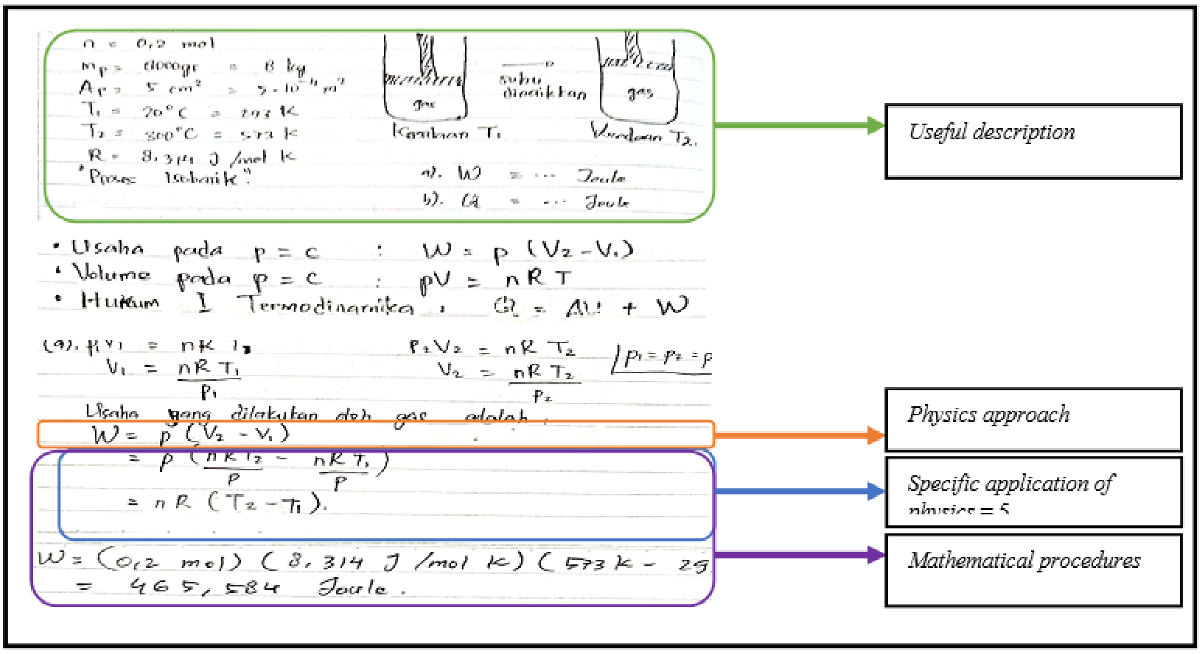


Figure 4. Analysis of Answers to Student Problem-Solving Abilities

To see an increase in student problem-solving based on problem-solving indicators through the results of student answers, it can be seen in Figure 5.

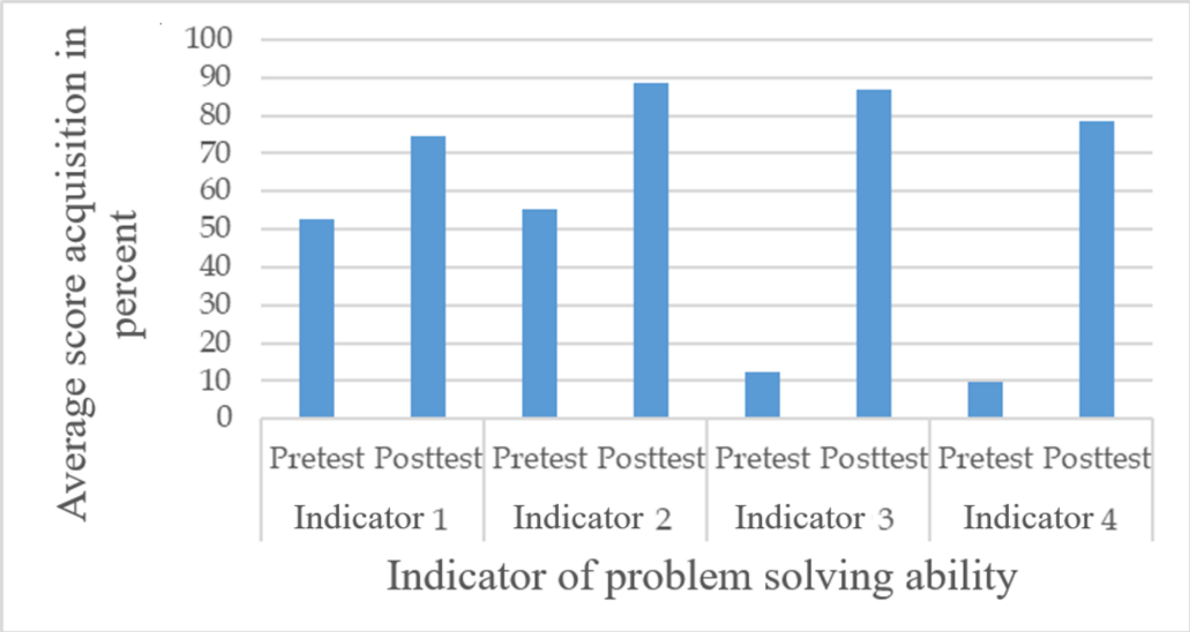


Figure 5. Student Problem-Solving Abilities According to Problem-Solving Indicators on The Pretest and Posttest

Discussion

Students' problem-solving skills are trained in the fourth stage of DL, namely topic discussion. At this stage, student groups use the asynchronous CPS approach to discuss the problems. The study results show that problem-solving exercises using the CPS approach can improve students' problem-solving skills (Eda & Purwaningsih, 2020).

The analysis results show an increase in students' problem-solving abilities after implementing DL using the CPS approach on thermodynamics material. Improvement in problem-solving abilities can be seen from the increase in student post-test scores. The amount of n-gain obtained is 0.72, which is in the high category. The magnitude of the influence of DL with the CPS approach on students' problem-solving abilities can be seen from the effect size value obtained at 3.75 in the strong category.

Student problem-solving abilities can be seen through problem-solving indicators: useful description, physics approach, specific application of physics, and mathematical procedure. After conducting DL using the CPS approach, the four indicators of student problem-solving increased to 74% in the useful description, 89% in the physics approach, 87% in the specific application of physics, and 79% in the mathematical procedure.

The first indicator is the useful description. This indicator is trained in the problem identification step in the CPS approach. Students can identify the problems given properly and are in the expert category. Students are said to be experts in solving problems and can describe problems and present information to determine the steps for solving them (Docktor & Mestre, 2014). However, some students still need to describe the problem in helping to identify the problem.

Indicator II is the physics approach. This indicator is trained in the main step in the problem-solving exercise using CPS. After implementing DL using the CPS approach, students can determine thermodynamic principles that will be used to solve problem-solving. The principles obtained are not directly used to solve problems but must be adapted to the problems to be solved. Student steps in adjusting and modifying the thermodynamic principles used to solve problems are part of indicator III, namely the specific application of physics. These two steps are important in solving the problem. The increase in students' problem-solving abilities in indicators II and III occurs due to practising using the CPS approach in the justification step, making students choose the correct thermodynamic equation (Eda & Purwaningsih, 2020). However, some students still need to complete this step in solving the problem. Previous research also explains that students have a habit of solving problems that are not carried out systematically and pay little attention to the steps for solving them, which are only concerned with the final result. (R. Azizah et al., 2015).

Indicator IV is a mathematical procedure. This indicator is trained in problem-solving exercises using the CPS approach in the plan step. Students develop steps to solve problems and use mathematical calculations to solve problems. Mathematical procedure indicators can increase after learning to use the CPS approach because students are already able to use concepts and understand their relationship with these concepts (Eda & Purwaningsih, 2020). The findings in this study are that many students need to include units of thermodynamic quantities in solving problems, so they do not know the meaning of the solutions obtained. Mathematical equations are different from physical equations, in physics equations have conceptual meanings related to symbols and their relationship to physical quantities and units (Docktor & Mestre, 2014).

CONCLUSION

There was an increase in student problem-solving abilities at DL using the CPS approach. The increase in student problem-solving abilities is indicated by the n-gain value, which is in the high category. DL using the CPS approach influences problem-solving abilities as indicated by the effect size value, which is in the strong category. After doing the problem-solving exercise using the CPS approach in DL, students can already solve problems using the useful description, physics approach, specific application of physics, and mathematical procedure stages. This research still needs improvement; it is necessary to conduct further research on DL with the CPS approach on other ability variables and other subject matter. Research is needed to link mastery of concepts and problem-solving abilities.

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