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Problem Solving Thinking Skills: Effectiveness of Problem-Solving Model in Teaching Chemistry College Students

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Abstract: Problem-solving is considered one of the thinking skills that must be possessed in 21st-century education because problem-solving skills are needed to solve all problems that arise. This study aims to describe problem-solving thinking skills as a manifestation of the effectiveness of problem-solving models in college student chemistry learning. The research method uses descriptive research with a quantitative approach. The design used is One Group Pretest-Posttest Design. This research was conducted in the chemistry department Universitas Negeri Surabaya with the subjects of 31 college students who programmed basic chemistry courses on chemical thermodynamics. Measurement of problem-solving thinking skills using a paper-pen test (pretest and posttest) in the form of an essay. This research findings show that: (1) Each indicator of problem-solving thinking skills of trained college students gets percentage, namely understanding problems 76.08%, planning problem solving 80.65%, implementing problem-solving 85.49%, drawing conclusions 78.50%, and evaluating problem-solving results 68.22%; and (2) N-gain scores for each indicator of problem-solving thinking skills obtained have medium and high criteria. Based on the research results, the problem-solving model has been effective in improving college students' problem-solving thinking skills.

Keywords: Problem-Solving model; Thinking skills; Effectiveness; Teaching Chemistry.

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Introduction

Higher education is part of the national education system that has a strategic role in the intellectual life of the nation. Students are one of the important pillars of the nation's next-generation in higher education, so the learning process must focus on increasing students' ability to solve problems in order to hone their skills and produce outputs that are ready to face challenges in the 21st century. The Partnership for 21st Century Skills defines three general 21st century skills, namely 1) skills related to information and communication; 2) thinking and problem-solving skills; and 3) interpersonal skills and self-regulation skills (Redhana, 2018). Therefore, learning in higher education must also teach college students 21st-century skills, not just the transfer of material, one of which is thinking and problem-solving skills.

The ability of college students to be successful in solving chemistry learning problems is largely determined by their problem-solving thinking skills. Through problem-solving thinking skills, students can train and develop their cognitive intelligence and are able to connect various facts or information with the knowledge they already have to make a prediction of the final result that is formulated. Therefore, problem-solving thinking skills are essential competencies that college students must have (Greiff et al., 2013). Problem-solving thinking skills are a series of thinking processes to find the right way to get a solution to a problem (Widiasih et al., 2018). This is in accordance with an opinion that college students who have good thinking skills in solving problems will easily apply their

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knowledge in any situation and point of view (Cheng, et.al. 2018), so problem-solving thinking skills are aspects that must be considered and developed by lecturers, especially in chemistry.

Chemistry is a branch of science, that has a discussion about the composition, structure, properties, changes, and energy that accompanies it. In addition, in chemistry, various concepts, theories, and laws are also compiled based on existing natural phenomena (Sirhan, 2007). One of the topics in chemistry is chemical thermodynamics. Chemical thermodynamics material is one of the materials in chemistry that can support individuals in problem-solving thinking skills. Various problems in everyday life such as changes in body temperature, dew outside the glass, how the thermos works, motor vehicle engines, refrigerators, and air conditioners, are some of the problems that can be solved using the concept of chemical thermodynamics so that students can learn the concepts of chemical thermodynamics by good, of course, it will make students tend to be able to solve various problems that exist in the field. In other words, college students who can study chemistry well, including in this chemical thermodynamics' material, will be able to become good problem solvers in society (SCE, 2012).

Problem-solving skills are the brain's ability to find solutions to problems by linking the solution objectives with possible problem-solving paths (Wang & Chiew, 2010). Connecting the solution goals with problem-solving paths requires higher-order thinking skills in the form of thinking skills to analyze, evaluate, and create (Anderson & Krathwohl, 2001), which operationally require thinking skills related to data interpretation, problem-solving design, critical analysis of literature, and work collaborative (Airey & Linder, 2009). Problem-solving thinking skills can be in the form of recognizing problems, analyzing problems, finding ways to deal with problems, implementing problem-solving plans, analyzing data, recognizing logical relationships between problems, evaluating problem-solving results, and drawing conclusions (Yurief, et.al., 2017). In line with the statement above, in finding a problem solution there are four steps that must be taken according to the Problem-Solving Polya learning model, namely: (1) understanding the problem, (2) determining a problem-solving strategy plan, (3) completing a problem-solving strategy, and (4) re-examined the results obtained (Polya, 1973).

The Problem-Solving Model can be interpreted as a series of learning activities that emphasize the process of solving problems faced scientifically. Based on Polya's steps, it can be illustrated that learning begins with giving problems, then college student practice understanding, formulating strategies, and implementing strategies to draw conclusions, and evaluate learning activities that have been carried out. Solving these problems can help students to solve problems or tasks in stages given by lecturers to students.

In problem-solving, college students are more active and creative in creating solutions to a given problem, so that students are able to propose problem-solving strategies and are able to develop a plan in implementing problem-solving (Aldous, 2005). The four stages of Polya's problem solving are a very important unit to be developed in training students' problem-solving thinking skills. This statement is reinforced by research results which show that problem solving-based learning can train students' problem-solving thinking skills in acid-base material (Laila & Azizah, 2017).

However, in a study conducted by (Hariawan et al., 2014), it was shown that the problem-solving skill score of students from the creative problem-solving learning experimental class only reached 45% of the expected ideal score. This is also supported by the percentage of the problem-solving index of some students which is still below 75%, which also means that students' problem-solving skills are still lacking (Nikat & Latifah, 2018). In addition, in 2018, based on the results of the PISA survey which included a student problem-solving skill component, it showed that 70% of Indonesian students were unable to reach level 2 in the PISA framework, even though on average only about 23% of students in 79 participating countries PISA who are unable to master reading ability level 2 (OECD, 2019). This shows that the literacy of Indonesian students, which also includes problem-solving skills, is still very low.

Based on the results of PISA and several studies above, it is necessary to conduct further research on the problem-solving thinking skills possessed by college students, so that in the future appropriate learning can be formulated to support students' problem-solving skills. In this research, a problem-solving model was implemented using problem-solving-based teaching materials that researchers had developed previously and were feasible based on the assessment of the validators (Azizah et. al., 2019). This implementation is carried out to describe the learning outcomes of problem-solving skills that are trained holistically when delivering chemical thermodynamics material. The learning activities are repeated in each different topic on chemical thermodynamics material, thus providing sufficient experience. Repeated experiences provide opportunities for students to gain knowledge retention and learning experiences.

Method

This research is a pre-experimental research design using One Group Pretest Posttest Design. Researchers give treatment or treatment to a group without a

comparison class (Fraenkel & Wallen, 2003). The target of this study was 31 students of the chemistry education study program at the Universitas Negeri Surabaya, Indonesia who programmed basic chemistry courses on chemical thermodynamics matter**. O**utlines the stages of the research as follows.

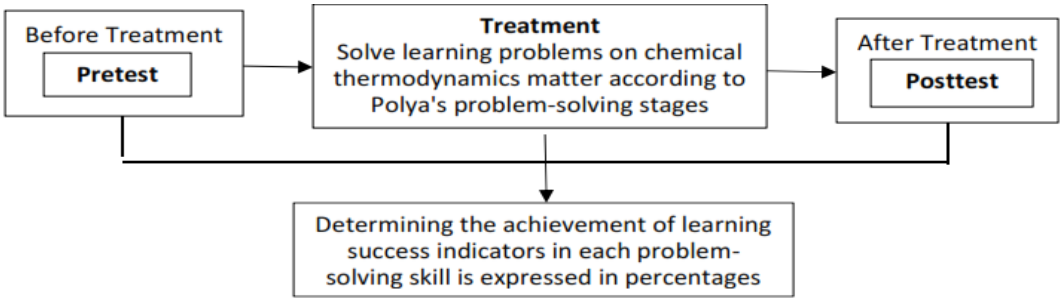


Figure 1. Research Process

Problem-solving model-based learning materials used require students to solve a chemical thermodynamics problem in accordance with Polya's problem-solving stages. The measurement of problem-solving thinking skills uses a paper-pen test (pretest and posttest) in the form of an essay that has been worthy of expert results and tested. Construct validity and content validity were validated by 3 experts at 93.12% and 87.78% respectively, while the test results (empirical validity) were obtained at 83.55% and 78.06% (Azizah, et.al., 2019).

The results of this study were analyzed by descriptive quantitative. The data collected in the learning outcomes contained in the students' pretest and posttest answers on each topic of chemical thermodynamics material. Aspects of problem-solving skills that are determined are measured based on the assessment rubric. The measurement results become a reference for determining the achievement of learning success indicators in each problem-solving skill expressed in percentages. Furthermore, the percentage of achievement indicators of problem-solving is categorized according to the following table (Budiyono, 2015).

Table 1. Category of the achievement of the indicator of problem-solving thinking skills.

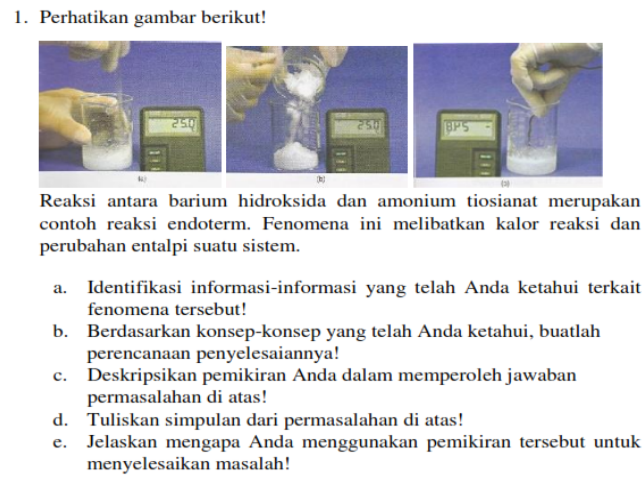
Percentage Interval (%)	Category
$85 \leq x \leq 100$	Very good
$70 \leq x < 85$	Good
$55 \leq x < 70$	Moderate
$40 \leq x < 55$	Poor
$0 \leq x < 40$	Very Poor

College students are said to be successful on each indicator of problem-solving thinking skills if they have a minimum achievement percentage of 70. The increase in problem-solving thinking skills test results is calculated using a Gain score. Descriptive analysis of N-gain using N-Gain criteria, namely: 1) "N-gain-high", if <g> > 0.7; 2) "N-moderate gain", if 0.3 < <g> 0.7; and 3) "N-gain-low", if <g> 0.3. (Hake, 2002).

Result and Discussion

The effectiveness of the learning model shows the ability of the learning model to produce an impact or achieve the desired learning objectives (Plomp & Nieveen, 2010). The effectiveness of this learning model is evaluated based on the achievement of problem-solving thinking skills which are the instructional effect of the implementation of problem-solving-based chemical thermodynamics learning materials.

Problem-solving thinking skills are college students' skills in using concepts, principles, and theories in problem-solving situations as indicated by the scores obtained by college students on the problem-solving thinking skills test (pretest and post-test) for chemical thermodynamics material. The questions used in measuring thinking skills are questions that require college students to carry out a thinking process based on the indicators of problem-solving thinking skills, namely understanding problems (A), planning problem solving (B), implementing problem-solving (C), drawing conclusions (D), and evaluating problem-solving results (E). Example of a question used to measuring problem-solving thinking skills in Figure 2.



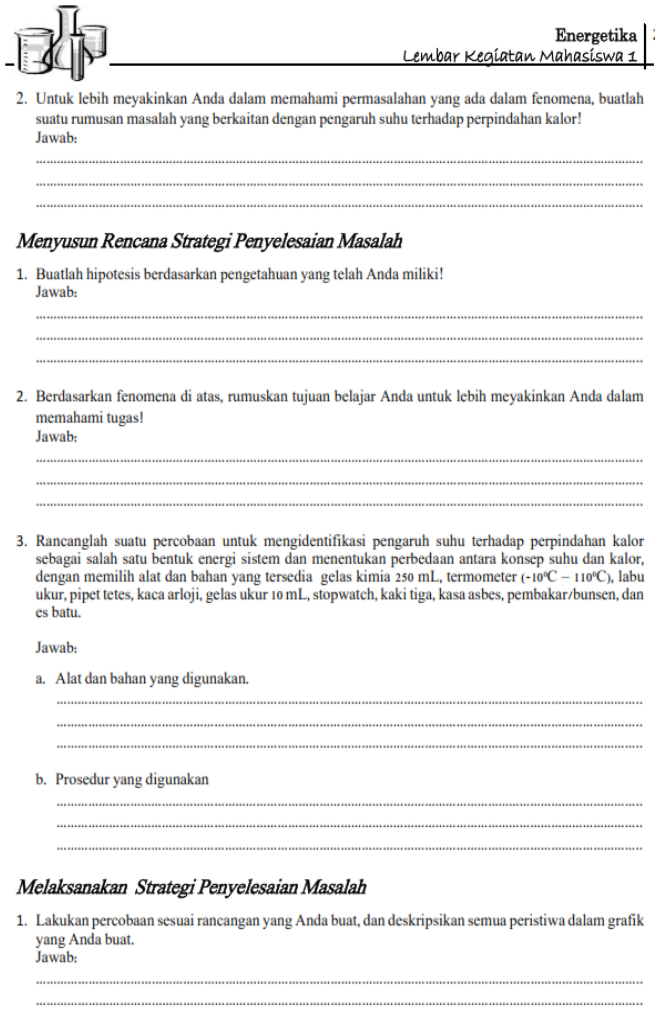
1. Perhatikan gambar berikut!

Reaksi antara barium hidroksida dan amonium tiosianat merupakan contoh reaksi endoterm. Fenomena ini melibatkan kalor reaksi dan perubahan entalpi suatu sistem.

a. Identifikasi informasi-informasi yang telah Anda ketahui terkait fenomena tersebut!
b. Berdasarkan konsep-konsep yang telah Anda ketahui, buatlah perencanaan penyelesaiannya!
c. Deskripsikan pemikiran Anda dalam memperoleh jawaban permasalahan di atas!
d. Tuliskan simpulan dari permasalahan di atas!
e. Jelaskan mengapa Anda menggunakan pemikiran tersebut untuk menyelesaikan masalah!

Figure 2. Questions of problem-solving thinking skills

After the pretest, the lecturer implements problem-solving-based teaching materials that begin with the step of understanding the problem, students must identify known knowledge based on phenomena related to the material to be studied and set learning goals. The next step is for students to plan problem-solving, which is followed by college students implementing problem-solving strategies through exploring concepts and facts as a basis for formulating problems, formulating hypotheses, carrying out experimental procedures, making observations, analyzing data, and making conclusions. At the end of the lesson, college students evaluate the performance that has been done in constructing the concept. An example of problem-solving-based teaching materials in Figure 3



Energetika
Lembar Kegiatan Mahasiswa 1

2. Untuk lebih meyakinkan Anda dalam memahami permasalahan yang ada dalam fenomena, buatlah suatu rumusan masalah yang berkaitan dengan pengaruh suhu terhadap perpindahan kalor!
Jawab:

Menyusun Rencana Strategi Penyelesaian Masalah

1. Buatlah hipotesis berdasarkan pengetahuan yang telah Anda miliki!
Jawab:

2. Berdasarkan fenomena di atas, rumuskan tujuan belajar Anda untuk lebih meyakinkan Anda dalam memahami tugas!
Jawab:

3. Rancanglah suatu percobaan untuk mengidentifikasi pengaruh suhu terhadap perpindahan kalor sebagai salah satu bentuk energi sistem dan menentukan perbedaan antara konsep suhu dan kalor, dengan memilih alat dan bahan yang tersedia gelas kimia 250 mL, termometer (-10°C – 110°C), labu ukur, pipet tetes, kaca arloji, gelas ukur 10 mL, stopwatch, kaki tiga, kasa asbes, pembakar/bunsen, dan es batu.

Jawab:

a. Alat dan bahan yang digunakan.

b. Prosedur yang digunakan

Melaksanakan Strategi Penyelesaian Masalah

1. Lakukan percobaan sesuai rancangan yang Anda buat, dan deskripsikan semua peristiwa dalam grafik yang Anda buat.
Jawab:

Figure 3. Problem-solving-based teaching materials

Through the implementation of problem-solving-based chemical thermodynamics learning materials, the results obtained are expressed in terms of the percentage of results for each indicator of problem-solving thinking skills presented in Figure 4.

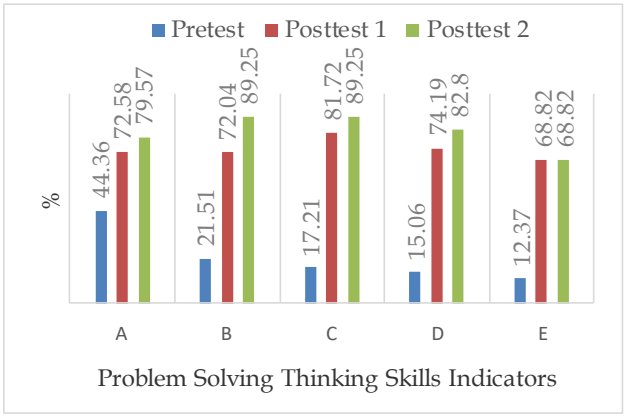


Figure 4. Achievement of indicators of problem-solving thinking skills

Based on Figure 4 the average achievement of the understanding problems (A) indicator of 76.08% is in a good category. That means 24 students have been able to understand the problem well which is indicated to be able to write information based on phenomena and set learning goals correctly. The percentage is lower than the indicators for planning problem solving (B), implementing problem-solving (C), and drawing conclusions (D) which are 80.65%, 85.57%, and 78.50%, respectively, in the good category. The sufficient category only achieved was an indicator evaluating problem-solving results (E) of 68.82%, meaning that only 21 students could review the answers.

Mastery of problem-solving thinking skills that were trained in two consecutive meetings of chemical thermodynamics material, obtained an increase in all indicators except indicator evaluating problem-solving results (E). This phenomenon shows that the intensity of the exercise plays a role in the acquisition of most problem-solving thinking skills.

According to social-cognitive theory, learning is modeling and cognitive processing of modeling (Moreno, 2010), so the repeated practice of the topic of chemical thermodynamics can be viewed as a modeling in studying chemical phenomena. In this case, students evaluate and appreciate the stages of problem-solving to be able to plan how to study chemical thermodynamic phenomena using problem-solving models. Modeling allows the emergence of ideas and the development of the concepts being studied. The existence of these better results shows that problem-solving-based teaching materials can improve problem-solving thinking skills, and college students become more critical, both in identifying problems, expressing opinions, asking questions, and planning to solve existing problems (Darmawan, 2010).

Figure 4 also illustrates that many college students do not have thinking skills before implementing problem-solving-based teaching materials, which is indicated by the small percentage of college students on

all indicators of problem-solving thinking skills. The low thinking skills of students on the pretest are due to problem-solving thinking skills that have not been trained in a structured and intensive way of learning. After the implementation of problem-solving-based teaching materials, the percentage of college students increased which indicated that problem-solving-based teaching materials were effective for training college students' problem-solving thinking skills. The highest percentage of problem-solving thinking skills indicator is implementing problem-solving (C) and the lowest is evaluating problem-solving results (E).

The good category on the understanding problems (A) indicator shows that college students are able to understand and search for information carefully and well. These results also show that the indicator of understanding the problem is an indicator that can be mastered by college students in their problem-solving thinking skills, such as the results of research conducted by (Aji & Mahmudi, 2018), and (Yanti et al., 2016). Kaya et al. (2014) stated that identifying problems and information that supports problem-solving is the initial stage of problem-solving. Meanwhile, in several studies, students' problem-solving skills develop well when lecturers relate learning to their real lives and by providing training to understand strategies (Irwanto et al., 2018).

College students who can understand the problem well will also tend to be able to analyze the problem and relate the various information obtained well. The problem analysis stage is also an important stage in problem-solving skills. At this stage, college students are required to assume, as well as process various information obtained properly and correctly, when students are wrong in analyzing a problem, then the follow-up actions taken by students at the stage of problem-solving skills will also experience errors (Nyachwaya et al., 2014).

The findings of the research on planning problem solving (B) indicators with good categories are in line with Anderson's (2011) research which states that strategy is an important part of problem-solving. By writing strategies, various alternative solutions and solution schemes designed for college students will be identified, from which we can find out how far students understand the problem.

The good category obtained in the implementing problem-solving (C) indicator shows that college students have no difficulty in implementing the plans that have been made, although there are some students who still find it difficult. The difficulties experienced by some college students were caused by the planning of problem-solving which was sometimes illogical and not in accordance with the existing theory so that when students were in the implementing problem-solving stage, the student's answers were incorrect. This finding is in accordance with research from (Yanti et al., 2016) which states that students who design problem-solving but are not logical, will make the implementation of the student's plan inappropriate and not in accordance with the intended solution plan.

The research findings on the drawing conclusions (D) indicators with good categories are the final result of concept construction from the problem-solving process carried out by college students. There are some college students who have not been able to make conclusions correctly because they do not understand the material well.

The ability to evaluate problem-solving results (E) is included in the moderate category compared to other problem-solving thinking skills. College students do not feel the need to check their answers again, because students believe that the plan designed has been optimal and does not need to be evaluated again. This is in line with the results of research conducted by Sanjaya et al. (2017) that students tend to feel confident and satisfied with a solution developed, without the need to look for other solutions or alternatives. In addition, college students are only concerned with the results obtained, which is in line with Thevenot and Barrouillet (2014) opinion that in reviewing answers, an individual must understand the contextual situation described in the problem, explore information, examine information in the relational structure of the plot, and finally make a decision in constructing the concept. These stages of course require complex thinking. Although the evaluating problem-solving results indicator has a moderate category, there are some college students who can get a maximum score in this indicator.

Furthermore, the N-Gain score is determined as a representation of increasing problem-solving thinking skills which is presented in Table 2.

Table 2. The average value of pretest, posttest, N-Gain, and the criteria for college student problem-solving thinking skills.

Indicators	Pretest (%)	Posttest (%)	N-Gain/ Criteria
Understanding problem	44.36	76.08	0.57/ moderate
Planning problem solving	21.51	80.65	0.75/high
Implementing problem solving	17.21	85.49	0.82/high
Drawing conclusions	15.06	78.50	0.74/high
Evaluating problem-solving results	12.37	68.82	0.64/ moderate

College students are declared successful on each thinking skill indicator if they have a minimum achievement percentage of 70. Based on Table 2, students still have not succeeded in completing one indicator, namely evaluating problem-solving results, although at each meeting they are trained in problem-

solving thinking skills in presenting complex problems. However, all indicators of problem-solving thinking skills have improved and are included in the medium and high criteria. The percentage of achievement of the indicator of problem-solving thinking skills is 77.91%, with an average N-gain in the high category. The findings of this study are the same as the results of previous studies (Wahyuni, et. al., 2017). Other studies also found that problem-solving model-based learning succeeded in growing students' problem-solving thinking skills in various academic fields (Hambach, et. al., 2016).

Practicing thinking skills in solving problems is closely related to the content of the material. On the other hand, the material content will be mastered well if the acquisition process is carried out through scientific ways of thinking in solving problems. This is in accordance with the opinion that thinking skills are trained and acquired in the context of specific material through certain strategies (Hoskinson et.al, 2013).

The learning process that occurs in each problem-solving cycle always begins with presenting material problems in the context of students. Problem presentations can activate prior knowledge that allows students to connect new information with existing knowledge (Schmidt, et.al. 2011). The activity of planning problem solving allows students to gain inquiry experience on complex tasks related to material phenomena (Dogru, 2008). The implementation of the problem-solving model allows repetition of practicing problem-solving thinking skills as well as reviewing concepts. This can improve memory through knowledge review activities to gain knowledge retention (Destalia, 2014).

In problem-solving, lecturers do not provide knowledge as a result, but students must seek and find them through searching activities or acting as problem solvers (Syofyan & Halim, 2016). Exploration of concepts and facts in lectures is a learning process that occurs directly and is referred to as enactive learning (Moreno, 2010). When students experience learning through problem-solving, they have more potential in finding various alternative solutions to problems, developing new understandings, and increasing their ability to understand problems in depth (Brenda & Tyrie, 2009).

The application of teaching materials based on problem-solving models plays an important role in improving students' problem-solving thinking skills. Because these teaching materials have given students the opportunity to determine learning objectives through the phenomena presented. Next, students determine possible solutions to the problem by associating theory with practical steps that are appropriate to the problem, then determining the most appropriate solution or plan to solve the problem. In the next stage, students must be able to implement the plan appropriately, conclude, and evaluate the implementation. This is in accordance with the explanation of Liliasari (2005), problem-solving uses basic thinking processes to solve a known or defined difficulty, assembles facts about difficulties and finds additional information needed inferences or suggests alternative solutions and tests them for the suitability, simplifies annotations and eliminating discrepancies, providing solution checks for generalizable values.

Based on the explanations above, it indicates that the implementation of the problem-solving model is effective in improving students' problem-solving thinking skills.

Conclusion

Based on the research results above, the conclusions that can be drawn are: (1) Each indicator of problem-solving thinking skills of trained college students gets percentage, namely understanding problems 76.08%, planning problem solving 80.65%, implementing problem-solving 85.49%, drawing conclusions 78.50%, and evaluating problem-solving results 68.22%; and (2) N-gain scores for each indicator of problem-solving thinking skills obtained have medium and high criteria. Based on the research results, the problem-solving model has been effective in improving college students' problem-solving thinking skills.

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