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Cognitive Flexibility in Developing Higher-Order Thinking Skills in the Course of Ring Theory

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Abstrak

Mata kuliah Teori Ring merupakan salah satu mata kuliah bidang matematika yang cukup ketat dalam memberlakukan sistem deduktif-aksiomatik, namun mahasiswa kesulitan memecahkan masalah karena kurang bisa berpikir secara fleksibel saat menerima informasi baru. Tujuan penelitian ini adalah untuk mengetahui hubungan antara *cognitive flexibility* dengan keterampilan berpikir tingkat tinggi atau *Higher-Order Thinking Skills (HOTS)*. Metode penelitian yang digunakan adalah korelasional *Ex Pose Facto*. Penelitian dilakukan di Prodi Pendidikan Matematika UIN Sunan Gunung Djati Bandung dengan jumlah mahasiswa yang diteliti sebanyak 120 orang sebesar 1,2%. Teknik analisis data yang digunakan adalah uji regresi linier sederhana. Berdasarkan hasil penelitian dapat disimpulkan bahwa *Cognitive Flexibility* memiliki pengaruh positif terhadap kemampuan berpikir tingkat tinggi sebesar . Pengaruh positif ini bermakna semakin meningkatnya *Cognitive Flexibility* mahasiswa maka akan berpengaruh terhadap peningkatan Kemampuan Berpikir Tingkat Tinggi mahasiswa, sehingga akan memberikan *impact* pada kemampuan yang dihasilkan dari keterampilan mengerjakan soal *HOTS* terhadap kemampuan fleksibilitas kognitif yang pada akhirnya terwujud sebuah produk manusia yang siap menghadapi tantangan kompleksitas masalah.

Kata kunci: Keterampilan Berpikir Tingkat Tinggi, *Cognitive Flexibility,* Teori Ring

Abstract

The Ring Theory course is one of the mathematics courses that are quite strict in applying deductive-axiomatic systems, but students have difficulty solving problems because they are less able to think flexibly when receiving new information. This study aimed to determine the relationship between cognitive flexibility and Higher-Order Thinking Skills (HOTS). The research method used is correlational Ex Pose Facto. The research was conducted at the Mathematics Education UIN Sunan Gunung Djati Bandung with the number of students studying as many as 120 people amounting to 1.2%. The data analysis technique used is a simple linear regression test. Based on the study results, it can be concluded that Cognitive Flexibility positively influences higher-order thinking skills. This positive influence means that the increasing Cognitive Flexibility of students will affect the improvement of students' higher-order thinking skills, it will have an impact on the abilities resulting from the skills of doing HOTS questions on the ability of cognitive flexibility which ultimately materializes a human product that is ready to face the challenges of problem complexity.

Keywords: *Higher-Order Thinking Skills, Cognitive Flexibility, Ring Theory*

1. INTRODUCTION

Mathematics as a science is known as a deductive science (Winarso, 2014), salah One characteristic is that the statements obtained are the logical result of previously obtained truths, so that the relationship between concepts or statements in mathematics is consistent(Indah &; Nuraeni, 2021). Each science has characteristics, epistemologies, and studies that can distinguish one science from another including competencies and skills obtained through the study of that science. The skills required to face the demands of the times are increasingly complex and only those who have the ability needed will survive in exploring this life. The skills needed have also shifted, universities must respond quickly so that college graduates are ready and skilled to face the 21st century. Skills are expected in the 21st century that distinguish from previous years, namely in skills of cognitive flexibility and emotional intelligence (Sugilar & Nuraida, 2022).

The increasingly competitive demands of 21st-century capabilities demand four competencies, namely: Critical Thinking and Problem Solving, Creativity and Innovation, Communication and Collaboration (Widana et al., 2019). Oriented learning Higher-Order Thinking Skills (HOTS) It is needed by educators, to measure and find out the readiness and ability of students in higher thinking activities (Arifin, 2017). The Australian Council for Educational Research (ACER) states that higher-order thinking skills are processes: analyzing, reflecting, giving arguments (reasoning), applying concepts to different situations, structuring, and creating. Higher-order thinking skills are one of the important competencies in the modern world, so it is mandatory for every student (Widana et al., 2019).

To build capabilities in Critical Thinking and problem-solving, assessment instruments are directed at international standard questions, namely Higher-Order Thinking Skills (HOTS) or Skills Higher Order Thinking (Gradini, 2019). Critical Thinking and Problem Problem-solving, Creativity and Innovation, Communication, and Collaboration an integral parts of building skills in the 21st century, so they will impact the abilities resulting from problem-working skills HOTS to the ability of cognitive flexibility that ultimately manifests a human product that is ready to face the challenges of complexity of problems (Saraswati & Agustika, 2020). Steps in developing measuring instruments' critical thinking skills show the overall characteristics that an instrument must have (Arifin, 2017).

The research that will be carried out focuses on the material in the Ring Theory course. Ring Theory courses generally contain problems that require high reasoning power and a level of rigor, obeying the principles of theorems and postulates (Rosyid, 2019). The analysis and synthesis aspects of HOTS questions can build or develop cognitive flexibility (Abraham et al., 2021) so that what students learn in the Ring theory course is not only able to prove or solve problems based on the questions presented, but also build a flexible attitude in their lives (Married in 2014).

Cognitive flexibility is a person's ability to adapt cognitive processing strategies to deal with new and unexpected conditions in their environment (Cañas et al., 2006). Cognitive flexibility refers to our ability to detach from one task and respond to another or think of several concepts at once. A cognitively flexible person will be able to learn faster, solve problems more creatively, and adapt and respond to new situations more effectively (Zubaidah, 2018), which is why it is so important both in educational settings and in the workplace to have cognitive flexibility. To respond and prepare someone to have good cognitive flexibility, there needs to be suitable instruments for building cognitive flexibility (Prihatiningsih & Ratu, 2020), this is due to the complexity of existing problems so that by responding quickly to problems and immediately finding the best solutions needed today by being able to develop professionally and follow the changing work environment in the future.

The Ring Theory course is one of the mathematics courses that is quite strict in applying deductive-axiomatic systems (Septiati, 2021). To prove these theorems, students must have the prerequisite knowledge related to them. The level of difficulty of students learning this material is not fully known, but some students are confused about starting the proof process, the proof algorithm has not been understood and understood properly. The complexity of the material or problems in the Ring Theory course is in the form of problems HOTS focuses on analysis and synthesis (Abraham et al., 2021). Results of research conducted (Sugilar, 2017) State that the mathematical reasoning ability of mathematics education students is in the range of 54.6 (low) from the 100 assessment scale with a standard deviation of 1.94 The value indicates that the mathematical reasoning ability of mathematics education students in the category of lacking, logical thinking and courage to try (trial and error) Students are still low, they feel afraid of being wrong in expressing their ideas and ideas and are accustomed to routine problems as a result of which it is difficult to understand non-routine problems well. The concepts in the prerequisite material are poorly understood, these problems need to be handled immediately by striving for students to be able to understand real analysis material well through the development of cognitive flexibility skills.

The ability to analyze problems or synthesize students always gives birth to cognitive flexibility So he immediately and quickly resolves the problem (Mardiyanti, 2020). Of course, this problem will be an obstacle during lectures both for lecturers and for students. The rigor of these principles, facts, principles, and procedures will always build student construction in having skills and cognitive flexibility. Students will do construction based on cognitive systems that were previously owned. In this Ring Theory course, these skills are expected to be able to build new thinking constructions. One of the best ways to become more cognitively flexible is to expose yourself to new experiences and ways of doing things (Setiawati, 2016), but generally, they are not sure where to start. Students who showed strategy flexibility between tasks were more successful than students who persisted with the same strategy (Elia et al., 2009). It takes specific strategies and other goals from learning Ring Theory through problem development HOSTED (analysis and synthesis) so that there is a new experience in studying the material.

Based on the results of the study (Nurul Oktaviani et al., 2020) It can be concluded that there is a relationship between cognitive flexibility and problem-solving skills. The contribution of cognitive flexibility to problem-solving skills was 70.6%. Other studies reveal in classroom learning, it takes mathematical cognitive flexibility to be able to solve math problems with various ideas expressed by students (Rahayuningsih et al., 2020). Cognitive flexibility is the ability to switch attention between two aspects of a stimulus, and patterns (Kim et al., 2009). However, none of the research-focused studies correlated cognitive flexibility and higher-order skills in ring theory courses.

Based on this description, the author is interested in conducting research. In this case, it will be examined whether there is a relationship between higher-order thinking skills with students' cognitive flexibility skills and analyze the results of students' HOTS test questions in the Ring Theory course. The hope is that finding a relationship between higher-order thinking skills and cognitive flexibility can help teachers determine the right approach and learning model to improve the ability of students, especially higher-order thinking skills in the Ring Theory course.

2. METHOD

The research method used in this study is correlational. The population in this study is students who took Ring Theory courses in the 2020/2021 academic year. The technique in data collection used is using questionnaires and tests.

Questionnaires were used to collect cognitive flexibility data and tests were used to retrieve data on higher-order thinking skills. For questionnaires, validity tests and reliability tests were carried out. Of the 20 statement items, 15 statements were declared valid with the value of the Cronbach Alpha coefficient = 0.622. The instrument of higher-order thinking skills aspects of synthesis and analysis totals 4 questions. For each of the indicators with the value of the Cronbach Alpha coefficient = 0.75.

3. RESULT AND DISCUSSION

The research conducted was to analyze the relationship between higher-order thinking skills in ring theory courses in building cognitive flexibility. The samples used were 121 learners. In this study, data were obtained from tests and non-tests. The independent variable is cognitive flexibility (X). The dependent variable, namely higher-order thinking skills (Y), is measured using a test instrument in the form of 4 questions for each indicator. Based on the test results, students were unable to do 42% and students who were able to solve questions were 58%.

Table 1. Simple Linear Regression Test

Model	***Unstandardized Coefficients***		***Standardized Coefficients***	***t***	***Say.***	***Collinearity Statistics***	
	B	**Std. Error**	**Beta**			**Tolerance**	**BRIGHT**
(Constant)	3.237	.288		11.250	.000		
Cognitive Flexibility	*.149*	*.133*	*.111*	*1.116*	*.267*	*1.000*	*1.000*

The results of a simple linear regression test analysis using SPSS software version 19 for Windows can be seen in Table 1 and Table 2. Based on Table 1 Coefficient is obtained at $a = 3{,}237$ which shows that if there is no Cognitive Flexibility (X) then the consistent value of higher-order thinking Ability (Y) is 3.237. It shows that for every 1% increase in $b = 0.149$ Cognitive Flexibility (X), higher-order thinking Ability increases by 0.149. Since the value of the regression coefficient is $(+)$, it can thus be said that Cognitive Flexibility (X) has a positive influence on higher-order thinking Ability (Y). So the regression equation is obtained $Y = 3.237 + 0.149X$.

Table 2. Simple Linear Regression Test

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.111a	.012	.002	.26760

Based on Table 2, it is known that the R Square value of 0.012 this value means that the relationship of Cognitive Flexibility (X) to higher-order thinking Ability (Y) is 1.2%, while 98.2% of higher-order thinking Ability (Y) is influenced by other variables that are not studied.

By looking at the results of the data analysis, Cognitive Flexibility (X) has a positive influence on higher-order thinking Ability (Y) with a total influence of 1.2%. This positive influence means that the increasing Cognitive Flexibility (X) of students will affect the improvement of students' higher-order thinking Skills (Y).

The indicators developed on the test instrument are analytical and synthesis skills. The analytical aspect (C4) is an aspect that utilizes the capabilities of the previous aspects. This aspect of analysis includes 3 basic abilities, namely: analysis of elements, analysis of relationships, and analysis of rules. Meanwhile, the synthesis aspect (C5) demands the ability to rearrange problems and find relationships by compiling previously possessed knowledge. The synthesis aspect consists of two main abilities, namely: the ability to find relationships, and the ability to compile evidence (Amelia et al., 2015).

Question 1: Category C4 (Analysis)

If R is a ring with more than one element. Show that the zero element is not the same as the unit element R.

In the problem with this indicator, students are asked to prove that if there is more than one element in a ring, then the zero element is not the same as the unit element. Here are the students' answers regarding the first indicator.

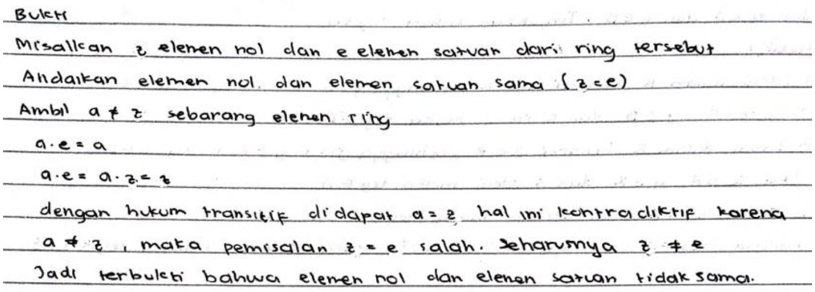

Bukti
Misalkan z elemen nol dan e elemen satuan dari ring tersebut
Andaikan elemen nol dan elemen satuan sama (z = e)
Ambil a ≠ z sebarang elemen ring
a · e = a
a · e = a · z = z
dengan hukum transitif didapat a = z hal ini kontradiktif karena
a ≠ z, maka pemisalan z = e salah. Seharusnya z ≠ e
Jadi terbukti bahwa elemen nol dan elemen satuan tidak sama.

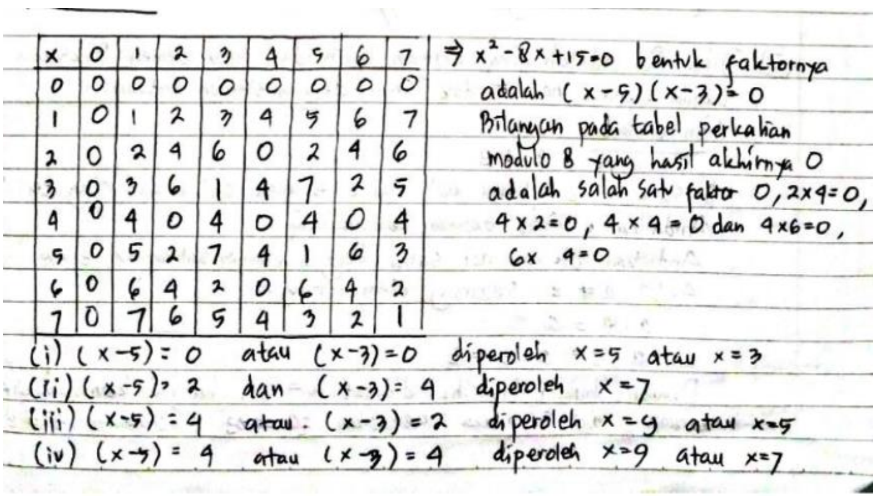
Figure 1. Answer to Question No. 1

In the answer to this question, students are required to think openly, which is to open the horizon of experience about the ring material. Looking at this problem from another point of view is to see the relationship between the zero element and the identity element in a ring. Students analyze the elements in the ring, namely the zero element and the unit element, each of which has certain characteristics and rules. If there is a unit element $e \in R$, then $a.e = e.a = a \in R$. In the properties of the ring, it can also be found $a.z = z, z,$ for $z \in R$ the zero element in a ring. (Wahyuni et al., 2016). Armed with this, students can find the relationship between the two and solve problem 1.

Question 2: Category C4 (Analysis)

If where $x, y \in B$ is the set of modulo integers 8. Find the roots of the quadratic equation $x^2 - 8x + 15 = 0$

In this problem, students are asked to find the roots of the quadratic equation from the set of integers modulo 8. Figure 2 shows the students' answers to question no.2



x	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	1	2	3	4	5	6	7
2	0	2	4	6	0	2	4	6
3	0	3	6	1	4	7	2	5
4	0	4	0	4	0	4	0	4
5	0	5	2	7	4	1	6	3
6	0	6	4	2	0	6	4	2
7	0	7	6	5	4	3	2	1

⇒ $x^2 - 8x + 15 = 0$ bentuk faktornya adalah $(x-5)(x-3) = 0$
Bilangan pada tabel perkalian modulo 8 yang hasil akhirnya 0 adalah salah satu faktor 0, 2x4=0, 4x2=0, 4x4=0 dan 4x6=0, 6x4=0

(i) $(x-5) = 0$ atau $(x-3) = 0$ diperoleh $x = 5$ atau $x = 3$
(ii) $(x-5) = 2$ dan $(x-3) = 4$ diperoleh $x = 7$
(iii) $(x-5) = 4$ atau $(x-3) = 2$ diperoleh $x = 9$ atau $x = 5$
(iv) $(x-5) = 4$ atau $(x-3) = 4$ diperoleh $x = 9$ atau $x = 7$

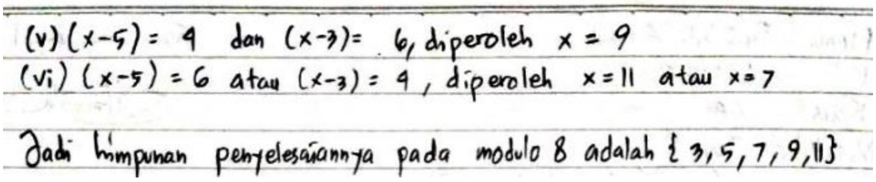

(v) (x−5) = 4 dan (x−3) = 6, diperoleh x = 9
(vi) (x−5) = 6 atau (x−3) = 4, diperoleh x = 11 atau x = 7
Jadi himpunan penyelesaiannya pada modulo 8 adalah {3, 5, 7, 9, 11}

Figure 2. Answer to Question No.2

In Figure 2 students can be seen calculating the roots of an equation. The root principle is the value of a variable that satisfies the equation. When this value is substituted, the equation returns zero. It is this value of zero that is then sought from the possibilities of the modulo integer eight. Students are asked to get out of the habit of counting on numbers from base ten to base eight. Students are asked to analyze the elements in the integer modulo eight that satisfy the quadratic equation in question while still being guided by the operating rules that exist in the integer modulo eight, then the intended roots will be obtained.

Soal 3 : Category C5 (Synthesis)

Let A *and* B *are ideals in ring* R $A \cap B = \{0\}$. *If* $x \in A$ *and* $y \in B$. *Show that* $xy = 0$.

In this problem, students are asked to prove that the multiplication of two elements equals zero. Both elements are members of a set that is both an ideal and a slice is a set that contains zero elements.

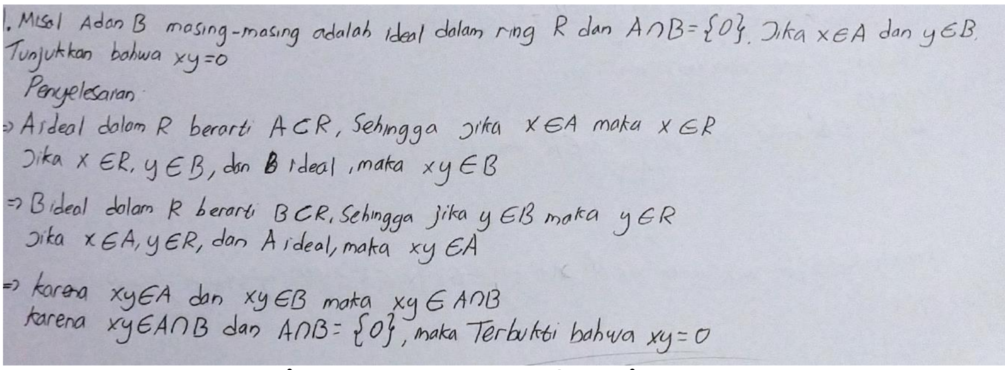

1. Misal A dan B masing-masing adalah ideal dalam ring R dan A∩B = {0}. Jika x∈A dan y∈B. Tunjukkan bahwa xy = 0
Penyelesaian:
⇒ A ideal dalam R berarti A⊂R, Sehingga jika x∈A maka x∈R
Jika x∈R, y∈B, dan B ideal, maka xy∈B
⇒ B ideal dalam R berarti B⊂R, Sehingga jika y∈B maka y∈R
Jika x∈A, y∈R, dan A ideal, maka xy∈A
⇒ karena xy∈A dan xy∈B maka xy∈A∩B
karena xy∈A∩B dan A∩B = {0}, maka Terbukti bahwa xy = 0

Figure 3. Answer to Question No.3

To solve this problem, students are asked to explore various ideas and ideas related to ideals. Problems related to set theory as a basis, such as subsets and intersections of two sets. To prove this problem, it is necessary to remember the definition of the ideal expressed in the following definition:

Definition 1. Let R ring and $I \subset R$. I is ideal if
1. $\forall x, y \in I$ so $x - y \in I$
2. $\forall r \in R$ and $\forall x \in I$, then $xr \in I$ and $rx \in I$

(Wahyuni et al., 2016)

From this knowledge of ideals, students can reconstruct problems and find relationships between some of the facts presented with knowledge of subsets and slices of both sets. This is a good capital to prove the No.3 question.

Soal No.4 Category C5 (Synthesis)

Consider the set N that consist of all matrices of the form $\begin{bmatrix} a & b \\ 0 & c \end{bmatrix}$ where a and b are real numbers, with the same rules for addition and multiplication as in matrices $M_{2\times 2}$.

In this problem, students are asked to prove the subring of a matrices that has been defined. As it is known that the matrices 2×2 is a ring.

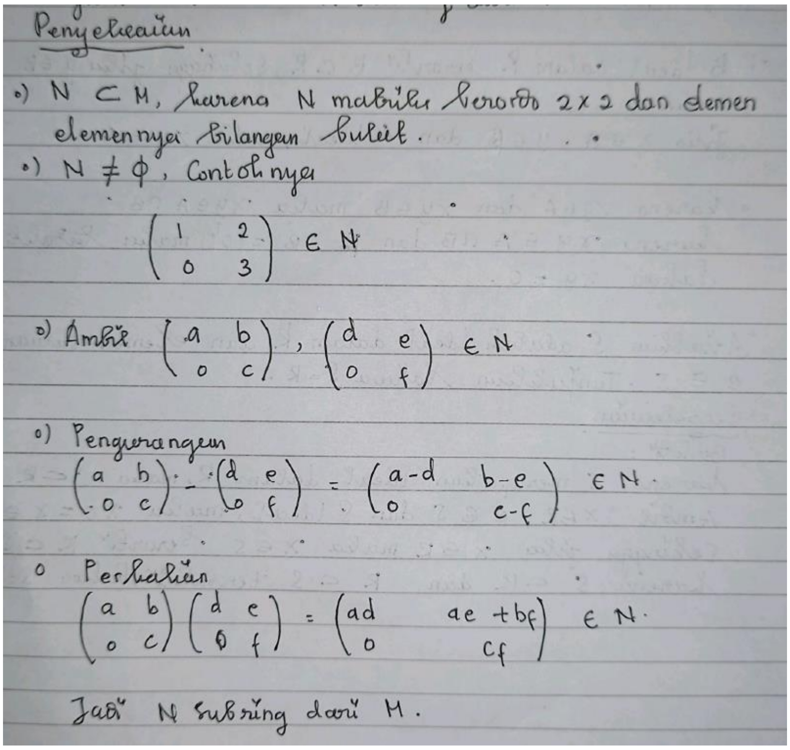


Figure 4. Answer to Question No.4

There are various ways to prove subring. By definition a subring is a nonempty subset of a ring with the same addition and multiplication operations as that ring (Wahyuni et al., 2016). In Figure 4, students can see the solution in proving a subring using one of the theorems of subring, which is as follows

Theorem 1: The subset S in the ring R is a subring of R if only if it satisfies
i) S non-empty
ii) $x \in S$ and then and $y \in S$, $x - y \in S, \ni xy \in S$

(Gilbert & Gilbert, 2000)

Using this theorem allows students to simplify several steps in proving a subring. These solving options make it possible to solve this evidentiary problem in various avenues and steps.

By looking at the synthesis and analysis problems that have been done by students, it can be seen that students already have the ability of higher-order thinking skills. This is proof of the contribution of cognitive flexibility. This ability drives the tendency to deal with difficult situations as something that can be controlled by utilizing the knowledge that has been previously possessed. Gather knowledge and stimulate the mind to be open and accommodate possibilities. Then, by looking at various alternatives in working on a problem cognitive flexibility also encourages the ability to understand some of these alternatives to solve the problems faced, so that students can produce several alternative solutions to solving them. (Dennis & Vander Wal, 2010).

4. CONCLUSION

From the results of the study, it can be concluded that Cognitive Flexibility has a positive influence on Higher Order Thinking Skills with a total influence of 1.2%. This positive influence means that the increasing Cognitive Flexibility of students will affect the improvement of students' Higher Order Thinking Skills. Student skills in solving analysis and synthesis-based questions by 58% show that the Cognitive Flexibility built during lectures helps students in solving HOTS questions.

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