***JKPK (JURNAL KIMIA DAN PENDIDIKAN KIMIA)**, Vol. 11, No. 1, 2026* *pp. 91-108*
Chemistry Education Study Program, Universitas Sebelas Maret *ISSN 2503-4146*
https://jurnal.uns.ac.id/jkpk *ISSN 2503-4154 (online)*

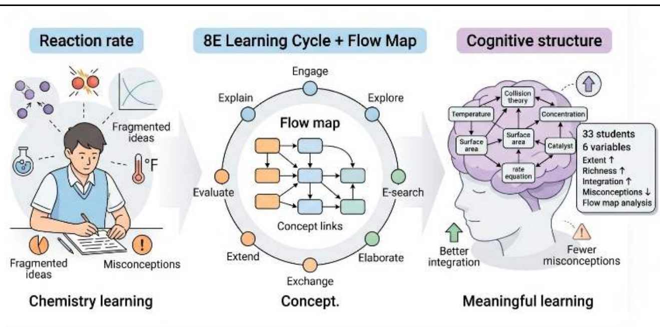
Mapping Minds in Chemistry: Implementing the Flow Map Method within the 8E Learning Cycle to Uncover Students' Cognitive Structures

Elma Suryani*, Achmad Ridwan, Rizky Sulistyowati, Edith Allanas, Sarina Hanifah, Fazila Windy Febriani, Ahmad Hafizh, Musyahadah Rodiatam Mardiah

Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta, Jakarta, Indonesia

ABSTRACT

Understanding students' cognitive structure is essential for improving conceptual learning in science, particularly in challenging topics such as the rate of reactions. However, many students struggle with fragmented knowledge and misconceptions in this area. This study investigates how the 8E Learning Cycle model supports the development of students' cognitive structure, analyzed through the flow map method. The participants were 33 Senior high school students, and a qualitative approach was employed using multiple data sources (flow maps, worksheets, interviews, journals, observations, and comprehension tests). Cognitive structure was examined based on Tsai's six variables: extent, richness, integration, misconceptions, information retrieval rate, and flexibility. Results indicated that at the beginning of instruction, students' average scores on cognitive structure variables were low, while misconceptions were frequent. After engaging in the 8E Learning Cycle, students demonstrated notable improvement across all variables, accompanied by a marked reduction in misconceptions. This study provides empirical evidence that the 8E Learning Cycle model effectively strengthens students' cognitive structures in science learning, offering a practical framework for addressing conceptual difficulties in reaction rate topics.



Keywords: *Cognitive Structure; Flow Map; 8E Learning Cycle; Rate of Reactions; Conceptual Understanding*

**Corresponding Author: elmasuryani@unj.ac.id*

How to cite: E. Suryani, A. Ridwan, R. Sulistyowati, E. Allanas, S. Hanifah, F. W. Febriani, A. Hafizh, and M. R. Mardiah, "Mapping minds in chemistry: implementing the flow map method within the 8E learning cycle to uncover students' cognitive structures," *Jurnal Kimia dan Pendidikan Kimia (JKPK)*, vol. 11, no. 1, pp. 91–108, 2026. [Online]. Available: https://doi.org/10.20961/jkpk.v11i1.110357

Received: 2025-10-25 *Accepted: 2026-03-17* *Published: 2026-04-30*

INTRODUCTION

Educational success can be examined through the learning process and the development of students' conceptual understanding. Strong conceptual understanding at the beginning of learning helps students accept new concepts more easily and supports later learning success. Low learning achievement is often closely related to students' cognitive structures that have not developed optimally. This is consistent with Zhou et al. [1], who reported that students with better learning outcomes tend to show better cognitive structure development.

Cognitive structures are often referred to as thought patterns, mental devices, or mental structures [2]. A cognitive structure can be understood as the way individuals organize and connect concepts in their minds [3]. Students need to continuously develop their cognitive structures because these structures influence how they process, connect, and retain new information. Well-developed cognitive structures support meaningful learning and help students integrate new knowledge more effectively. Weak or fragmented cognitive structures, however, may lead to misconceptions and difficulties in understanding abstract concepts [1], [3].

Learning models that are not aligned with students' needs may affect students' learning interest and conceptual understanding [4]. The 8E Learning Cycle is considered an appropriate learning model to support the development of students' cognitive structures. This learning model is based on constructivist principles, in which students are actively involved in exploring, developing, and connecting their prior knowledge with new learning experiences [5]. The 8E Learning Cycle also supports meaningful learning because it facilitates students in solving problems and understanding concepts through structured learning stages [6].

Chemistry is a subject that contains many abstract concepts, including decomposition, particle properties, and chemical bonding, which are fundamental to understanding chemical phenomena [7], [8]. Chemical concepts are commonly represented at three levels, namely macroscopic, submicroscopic, and symbolic representations. These representations are important for developing a complete understanding of chemistry, but they can also become a source of difficulty for students [8]. Mersa et al [9] reported that students consider reaction rate to be one of the difficult chemistry topics. Reaction rate concepts involve mathematical equations and several sub-concepts that are difficult to visualize because of their abstract nature. Students also tend to rely more on macroscopic representations than submicroscopic or symbolic representations when learning reaction rate concepts.

Ahiakwo and Isiguzo [10] reported that students' understanding of chemical kinetics was generally low, as only about 10% of students were able to identify correct answers in the conception test. Misconceptions related to reaction rate concepts were also reported by Lestari et al. [11] and Jusniar et al. [12]. These findings indicate that students need learning experiences that help them connect concepts, organize ideas, and reduce misconceptions in reaction rate learning.

This study used the flow map method developed by Anderson and Demetrius [13] to investigate students' cognitive structures. The flow map method is considered effective for describing students' cognitive structures because it can show the relationships among concepts, either sequentially or interconnectedly. Through flow maps, students' ideas can be visualized in a structured form, making it easier to identify how concepts are organized in their minds [13].

Some researchers suggest that cognitive structure can be described through three main aspects: the concepts or ideas obtained, the relationships among concepts, and information processing strategies [14], [15]. Compared with other cognitive structure analysis methods, the flow map method can represent these three aspects more explicitly. Vertical analysis of flow maps shows the sequential development of students' cognitive structures, while diagonal analysis reveals conceptual relationships among ideas [13].

Previous studies have examined students' cognitive structures, chemistry learning difficulties, reaction rate misconceptions, and the use of the flow map method. However, limited research has traced how students' cognitive structures develop across the stages of the 8E Learning Cycle in reaction rate learning. Therefore, this study offers novelty by integrating the flow map method with the 8E Learning Cycle model to examine students' cognitive structure development through six variables: extent, richness, integration, misconceptions, information retrieval rate, and flexibility.

METHODS

1. Research Design

This study employed a qualitative research design aimed at exploring students' cognitive structures in understanding the concept of reaction rate through the implementation of the 8E Learning Cycle model. The qualitative approach was chosen because it allows for an in-depth analysis of how students organize, connect, and interpret chemical concepts during the learning process.

The research procedure consisted of three main stages: preparation, implementation, and the final stage. The preparation stage focused on developing the theoretical and practical foundation of the study, including curriculum analysis, development of teaching modules based on the 8E Learning Cycle model, and the design of research instruments. The implementation stage represented the core of the research, where the 8E Learning Cycle learning model was applied in classroom instruction. The final stage focused on evaluating students' conceptual understanding and synthesizing the collected data.

2. Participants

The participants in this study were 33 eleventh-grade students from a senior high school who had studied the topic of reaction rate in chemistry. The participants were selected to represent students who participated in the learning process using the 8E Learning Cycle model. All students were involved in the comprehension test, while several students were selected for in-depth interviews to further explore their cognitive structures.

3. Research Instruments

This study employed six research instruments to collect data on students' conceptual understanding and cognitive structures. The first instrument was a comprehension test designed to identify students' understanding of reaction rate concepts. The test consisted of five descriptive questions representing the main subtopics of reaction rate. Prior to implementation, the test items were qualitatively validated by lecturers or subject matter experts to ensure their relevance, clarity, and appropriateness for the research objectives. The second instrument was semi-structured interview guidelines. These interviews were conducted to explore students' cognitive structures during the learning process using the 8E Learning Cycle model. The interviews allowed the researchers to obtain deeper information about students' ways of thinking, conceptual connections, and difficulties in understanding reaction rate concepts.

The third instrument was the flow map. Flow maps were used to visualize and describe students' cognitive structures by showing how students connected one concept to another. Students were asked to construct conceptual connections based on their understanding, and the resulting maps were analyzed to determine the complexity, accuracy, and organization of their conceptual knowledge. The fourth instrument was an observation sheet used to monitor teacher and student activities during the learning process. This instrument helped ensure that the 8E Learning Cycle model was implemented appropriately and consistently. The observation sheet also provided supporting data on classroom dynamics, student participation, and the interaction patterns that occurred during learning.

The fifth instrument was a reflective journal. Reflective journals were used to document students' reflections, responses, and learning experiences at the end of each learning session. These journals provided information about students' perceptions of the learning process, the concepts they found meaningful, and the difficulties they experienced during the activities. The sixth instrument was the student worksheet or LKS. The worksheets served both as learning aids and as data collection tools. They were used to document students' written responses, reasoning processes, and problem-solving strategies at each stage of the 8E Learning Cycle. All instruments were subjected to qualitative expert validation before being used in the study to ensure their suitability, content relevance, and alignment with the learning objectives.

4. Data Collection Techniques

Data collection was conducted during the implementation stage of the research through multiple techniques. The learning process used the 8E Learning Cycle model, which consists of Engage, Explore, E-search, Elaborate, Exchange, Extend, Evaluate, and Explain stages.

Classroom observations were conducted throughout the learning sessions to monitor interactions between teachers and students and to ensure that the learning model was implemented appropriately. Students completed worksheets to record their learning progress at each stage of the learning cycle. Students also created flow maps to represent their cognitive structures by illustrating relationships among concepts.

Reflective journals were written by students at the end of each learning session to describe their learning experiences and conceptual understanding. The final stage of the study required all 33 students to complete a comprehension test to measure their conceptual understanding after the learning intervention. In-depth semi-structured interviews were then conducted with selected students to obtain deeper insights into their cognitive structures and reasoning processes.

5. Data Analysis

The data analysis technique used in this study followed the qualitative analysis model proposed by Miles and Huberman [16], which consists of three main processes: data reduction, data display, and conclusion drawing/verification.

Data Reduction

Data reduction was conducted by selecting, simplifying, and organizing information obtained from tests, interviews, observations, worksheets, reflective journals, and flow maps. This process focused on data relevant to students' cognitive structures and conceptual understanding of reaction rate concepts.

Data Display

Reduced data were organized and presented in the form of tables, diagrams, flow maps, and descriptive explanations. This stage aimed to facilitate interpretation and support the identification of patterns in students' cognitive structures..

Conclusion Drawing and Verification

Conclusion drawing and verification involved interpreting the data to identify patterns, relationships, and conclusions regarding students' conceptual understanding and cognitive structures related to reaction rate concepts. Data validity and trustworthiness were ensured using the criteria proposed by Lincoln and Guba [17], which include credibility, transferability, dependability, and confirmability. Credibility was emphasized through prolonged engagement, member checking, persistent observation, and progressive subjectivity.

RESULTS AND DISCUSSION

1. Overview of Learning Implementation and Cognitive Structure Analysis

Table 1. Stages of implementations of the learning process

Cycle	Sub Material	Meeting	Learning Stages
I	Collision Theory and Reaction Rate	1	Engage Explore E-search Elaborate
		2	Exchange Extend Evaluate Explain
II	Factors Affecting Reaction Rate and Their Applications	3	Engage Explore E-search Elaborate
		4	Exchange Extend Evaluate Explain
III	Rate Equation and Reaction Order	5	Engage Explore E-search Elaborate
		6	Exchange Extend Evaluate Explain

This study examined students' cognitive structures related to reaction rate concepts using the flow map method within the 8E Learning Cycle model. The participants were 33 eleventh-grade senior high school students. Data were collected through student worksheets, reflective journals, flow maps, observation sheets, comprehension tests, and interviews to obtain a comprehensive description of students' conceptual understanding and cognitive structure development. The intervention was implemented over three weeks through six meetings organized into three learning cycles, as presented in Table 1.

Students' cognitive structures were analyzed using the flow map method during the Elaborate and Explain stages of the 8E Learning Cycle. The analysis focused on six cognitive structure variables proposed by Zhou et al. [1] and Tsai [3], namely extent, richness, integration, misconception, information retrieval rate, and flexibility. These variables were used to examine the development of students' cognitive structures after participating in learning activities based on the 8E Learning Cycle model.

The overall results indicate that most students experienced improvements in their cognitive structures, as reflected in the increased number of ideas, stronger conceptual connections, and reduced misconceptions between the Elaborate and Explain stages. The development of students' cognitive structures is presented in Figure 1.

The improvement in students' cognitive structures can be seen from the increasing number of ideas, stronger conceptual connections, and better integration among related concepts. The Exchange stage allowed students to discuss and compare ideas with peers, while the Evaluate stage allowed the teacher to clarify students' conceptual understanding. This finding is consistent with the role of the 8E Learning Cycle in supporting conceptual understanding through active learning, exploration, discussion, reflection, and conceptual reconstruction [6].

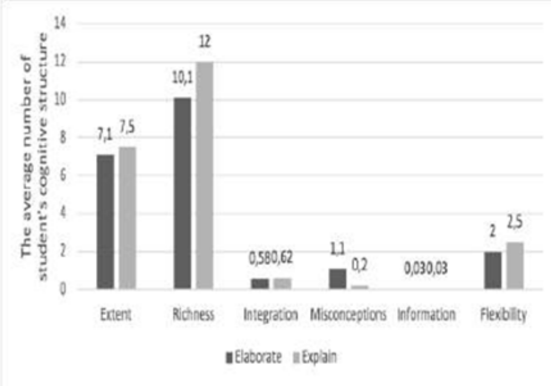


Figure 1. Graphic analysis of the development of students' cognitive structures

2. Implementation of Learning Reaction Rate Material Using 8E Learning Cycle model

The 8E Learning Cycle is a student-centered learning model consisting of eight stages: Engage, Explore, E-search, Elaborate, Exchange, Extend, Evaluate, and Explain. In this study, each cycle was conducted over two meetings.During the first meeting, students developed their understanding individually through the Engage, Explore, E-search, and Elaborate stages. In the second meeting, students collaborated in groups through the Exchange, Extend, Evaluate, and Explain stages.

a. Engage Stage

This stage is the initial stage of Learning Cycle 8E, at the beginning of entering the sub- material of collision theory and reaction rate, the teacher provides a case study on social interaction. Students are interested in observing the case study given by the teacher regarding the occurrence of chemical reactions and collision theory, as well as its relationship to reaction rates.

“I am happy today to learn about collision theory and reaction rate, I have never learned about the meaning of both materials using interesting animated videos. I want to know more about both materials and their formulas.”
(Student 04, Reflective Journal)

This response indicates that contextual media can stimulate students’ curiosity and support their initial engagement with abstract chemistry concepts. The Engage stage is important because students’ motivation and attention influence their readiness to construct new conceptual understanding [5], [6].

b. Explore Stage

Stage Explore aims to enable students to explore their initial knowledge related to the case study given at the stage engage.

"It turns out that the purpose of food in the refrigerator is to slow down the reaction rate so that it does not rot quickly, the rotting process is caused by bacteria or fungi through complex chemical reactions."
(Student 24, LKPD)

Student 24’s response shows that students began to connect everyday phenomena with the concept of reaction rate. The use of guiding questions in the Explore stage helped students examine prior knowledge, formulate initial hypotheses, and develop preliminary understanding of the material being studied. This process is consistent with constructivist learning principles and the role of learning cycle activities in encouraging students to actively build knowledge through exploration [5], [18].

c. E-Search Stage

The E-Search stage allowed students to seek information from various learning sources. Observation data showed that students mostly used smartphones and internet sources to find definitions and examples related to collision theory and reaction rate.

“Students are allowed to use the internet and books as their learning resources and many of them search for the definition of collision theory and reaction rate on smartphones, compared to books.”
(Observer 1, Observation Sheet)

This activity supported students in expanding their knowledge sources and comparing information from different references. The E-Search stage contributed to the development of students’ initial conceptual networks before they entered deeper learning activities.

d. Elaboration Stage

The Elaboration stage provided students with opportunities to develop what they had learned and apply new knowledge in a broader context. This stage allowed students to reflect on their understanding and connect prior knowledge with information obtained from learning sources [19].

"The higher the temperature, the faster the reaction rate, the lower the temperature, the slower the reaction rate. If the temperature de-creases, the reaction of microorganism generation is inhibited and the decomposition reaction is also inhibited, therefore food/drinks that are put in the refrigerator will last longer."
(Students 11, LKPD)

Student 11's response shows that the student was able to combine prior knowledge with information obtained from learning sources. The student connected the concept of temperature with reaction rate and applied it to the daily phenomenon of food preservation in a refrigerator.

e. Exchange Stage

The Exchange stage provided students with opportunities to discuss and exchange ideas with group members. Students were divided into five groups, and each group consisted of approximately seven students. This stage helped students compare ideas, clarify understanding, and discuss reaction rate concepts collaboratively.

"Today's practicum was fun, it helped me understand the reaction rate material more."
(Student 14, Reflective Journal)

"Very exciting, I like the practicum so I understand better. I will do the practicum more often."
(Student 20, Reflective Journal)

Student 14 and Student 20 indicated that practical activities helped them understand material that had previously been learned through reading and theory. Practical activities can support students with visual and kinesthetic learning tendencies because students can observe phenomena directly and construct understanding through active experience.

f. Extend Stage

The Extend stage gave students opportunities to reflect on their understanding after group discussions. Students were asked to express the results of their discussions through flow maps so that their conceptual relationships could be observed more clearly.

"Students write down the results of their discussions in the form of a flow map. There are students who write down the definition of the reaction order, there are also students who start writing down how to determine the value of the reaction order and the rate constant from the results of their discussions."
(Observer 2, Observation Sheet)

Observation results show that students were able to write answers in their own words based on concepts learned through group discussions. The Extend stage supported changes in students' conceptual knowledge because students obtained new information from peer interaction and discussion. This stage also helped students organize ideas before communicating their understanding in the Explain stage.

g. Evaluate Stage

The Evaluate stage involved clarification of the concepts being studied through dialogue between the teacher and students. The teacher acted as a facilitator who guided students to evaluate their understanding, clarify misconceptions, and refine their explanations. This role is consistent with the constructivist orientation of the 8E Learning Cycle, in which students are actively involved in learning while the teacher facilitates conceptual reconstruction [20].

"After you explained and gave me examples, I understood everything."
(Student 05, Interview)

Student 05 gave a positive response after the teacher explained, the student felt that he understood after it was explained because the student also did not hesitate to ask questions to the teacher, if there were some explanations that were not understood.

h. Explain Stage

This Stage is the final stage, at this stage, students convey their understanding of the reaction rate material after participating in the learning. Explain can train students' communication skills and self-confidence in conveying their understanding in front of teachers and friends.

"What I know about the reaction rate equation is the result of multiplying the reaction rate constant by the initial concentration of A and the initial concentration of B raised to the power of the reaction rate order. v = k [A]m[B]n v is the symbol for the reaction rate, k is the rate constant, then the concentration of reactant A, m is the power of the reaction order A and the concentration of reactant B, n is the power of the reaction order B"

(Student 31, Interview)

Student 31's response indicates that students were able to explain the reaction rate equation correctly. The Explain stage helped students consolidate their understanding, while teachers could identify students' conceptual mastery and provide additional clarification when necessary.

3. Analysis of Students' Cognitive Structure Using Flow Map Method

The analysis focused on six cognitive structure variables proposed by Tsai [3] , namely extent, richness, misconceptions, integration, information retrieval rate, and flexibility. Extent refers to the total number of ideas displayed in the flow map, whereas richness refers to the total number of arrows or linkages indicating recurrent associations among ideas. Misconceptions refer to the number of inaccurate or scientifically incorrect ideas identified in students' flow maps. Integration represents the proportion of repeated linkages in relation to the total number of ideas and linkages, calculated using the formula: integration = richness / (extent + richness). Information retrieval rate refers to the number of idea statements expressed per second, indicating how quickly students can recall and communicate their understanding. Flexibility refers to the number of additional ideas generated by students after receiving new information or engaging in further learning activities. In this study, the original meta-listening component was adapted and replaced with the e-search, exchange, and evaluate stages of the 8E Learning Cycle.

These six variables were used to examine different dimensions of students' cognitive structures. Extent and richness describe the quantity and connectedness of students' ideas, while integration indicates the degree to which these ideas are meaningfully linked. Misconceptions reveal the presence of inaccurate conceptual understanding, whereas information retrieval rate reflects students' ability to retrieve and express ideas within a limited time. Flexibility shows the extent to which students are able to add, revise, or reorganize their ideas after interacting with new information during the learning process.

Cognitive structure analysis was conducted not only through numerical calculation of the six variables, but also through qualitative coding of data obtained from interviews, observations, reflective journals, student worksheets, flow maps, and comprehension tests. The following sections present the analysis of students' cognitive structures based on three reaction rate sub-materials: collision theory and reaction rate, factors affecting reaction rate, and reaction rate equation with reaction order.

a. Collision Theory and Reaction Rate

The first sub-material analyzed was collision theory and reaction rate. This sub-material was selected because it represents the basic conceptual foundation for understanding how reactions occur and why reaction rates may differ under certain conditions. Students' flow maps were examined to identify how they organized ideas related to collisions, effective collisions, temperature, and reaction rate. The comparison between the Elaborate and Explain stages was used to determine whether students' cognitive structures became more developed after discussion, clarification, and explanation activities in the 8E Learning Cycle. The results of this analysis are presented in Table 2.

Table 2. Analysis of Cognitive Structure of Collision Theory and Reaction Rate Sub-Material

No.	Learning Stage	Variable	Student 05	Student 14	Student 22	Student 07	Student 20
1	Elaborate	Extent	8	7	12	6	6
		Richness	11	6	17	12	5
		Integration	11/(8+11) = 0.58	6/(7+6) = 0.46	17/(12+17) = 0.59	12/(6+12) = 0.67	5/(6+5) = 0.45
		Misconceptions	2	2	3	1	4
		Information retrieval rate	6/180 = 0.03	7/180 = 0.04	9/180 = 0.05	5/180 = 0.03	5/180 = 0.03
		Flexibility	8−6 = 2	7−7 = 0	12−9 = 3	6−5 = 1	6−5 = 1
2	Explain	Extent	9	6	12	7	5
		Richness	13	7	18	18	6
		Integration	13/(9+13) = 0.59	7/(6+7) = 0.54	18/(12+18) = 0.60	18/(7+18) = 0.72	6/(5+6) = 0.55
		Misconceptions	0	0	1	1	2
		Information retrieval rate	6/180 = 0.03	6/180 = 0.03	8/180 = 0.04	6/180 = 0.03	5/180 = 0.03
		Flexibility	9−6 = 3	6−6 = 0	12−8 = 4	7−6 = 1	5−5 = 0

The extent variable represents the total number of ideas displayed in the flow map. Table 2 shows that Student 05 wrote 8 ideas and Student 22 wrote 12 ideas in the Elaborate stage, indicating that both students produced more ideas than the other three students. The flow map produced by Student 05 is shown in Figure 2.

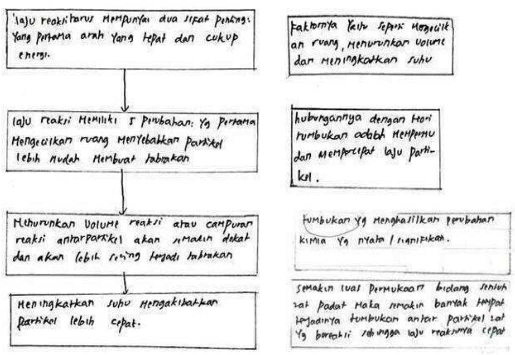


Figure 2. Student 05, flow map stage elaborate

Student 05 wrote down 8 ideas in a total flow map at the stage elaborate. This shows that student 05 reflects on initial knowledge with the information obtained. Because students have passed the stage to engage, explore, and e-search. This is reinforced by data from student worksheets.

> *"From the case study video, collisions and dropping books can make us form relationships, like chemistry the more collisions/crashes the more chemical reactions are formed, high temperatures also mean particles moving faster and there may be colli-sions that result in reactions" (Student 05, LKPD)*

Student 05 was able to explain the case study appropriately by connecting the analogy in the video with collision theory and the effect of temperature on reaction rate. This response indicates that contextual learning activities helped the student connect daily phenomena with scientific concepts.

The richness variable represents the number of repeated relationships among ideas. Table 2 shows that richness increased in several students, particularly Student 05 and Student 07. Student 07, for example, wrote 6 ideas with 12 repeated-link arrows in the Elaborate stage, then increased to 7 ideas with 18 repeated-link arrows in the Explain stage. This indicates that the student developed stronger conceptual relationships after completing the learning cycle stages. Student 07's flow map in the Explain stage is shown in Figure 3.

Student 07 organized ideas well in the flow map and was able to state that effective collisions are collisions that produce reactions with correct orientation. Table 2 also shows that Student 05 and Student 07 demonstrated relatively good cognitive structures in this sub-material. This finding was supported by their comprehension test results, as shown in Figure 4 and Figure 5.

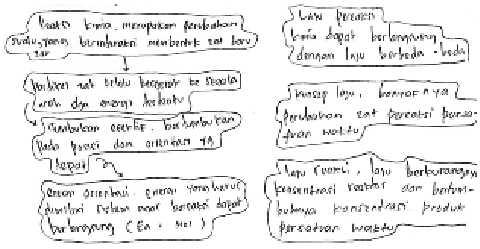


Figure 3. Student 07, flow map stage explain

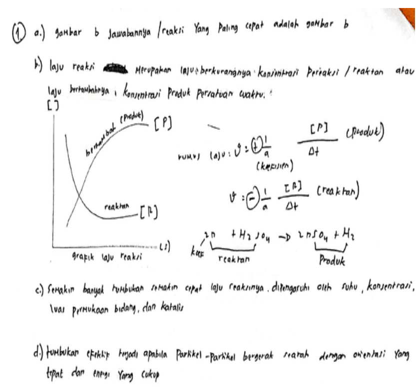


Figure 4. Student 05, Comprehension Test Instrument Results

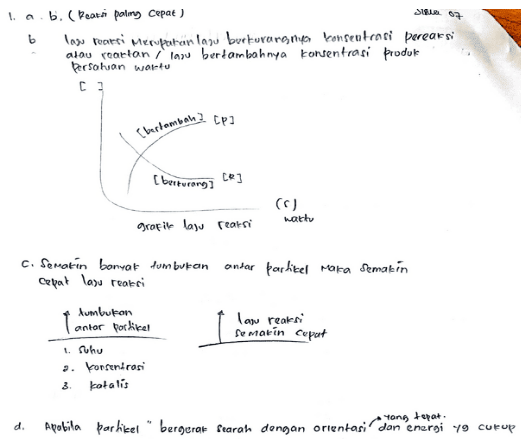


Figure 5. Student 07, Comprehension Test Instrument Results

The comprehension test results show that Student 05 and Student 07 answered questions on collision theory and reaction rate correctly, supporting the interpretation that both students developed more organized conceptual understanding after the learning process. The integration variable shows the proportion of repeated links in relation to the total number of ideas and repeated links. Student 07 had the highest integration value in the Explain stage, namely 18/(7+18) = 0.72, indicating that most ideas written by the student were strongly interconnected. The misconception variable represents scientifically inaccurate ideas in the flow map. Table 2 shows that misconceptions decreased from the Elaborate stage to the Explain stage, although Student 20 still showed four misconceptions in the Elaborate stage, as shown in Figure 6.

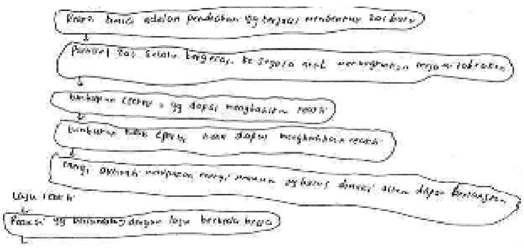


Figure 6. Students 20, flow map stage elaborate

Student 20 wrote that a chemical reaction is only a change that forms a new substance. A more complete scientific definition explains chemical reaction as a process in which substances change and form new chemical substances, involving reactants and products [21]. Student 20 also wrote that reaction rate is a reaction occurring at different speeds. The scientifically appropriate concept is that reaction rate refers to the change in reactant or product concentration per unit time [22].

The information retrieval rate variable represents the speed of idea retrieval, calculated from the number of ideas written within a given time. Table 2 shows that Student 22 had the strongest ability to write ideas quickly in flow map form. This result is consistent with Zhou et al. [1], who reported that students with better cognitive structures tend to express ideas and concepts more effectively.

The flexibility variable represents the number of additional ideas produced after students experienced E-search, Exchange, and Evaluate activities. Table 2 shows that Student 05, Student 22, and Student 07 added ideas between the Elaborate and Explain stages. This indicates that the learning activities helped students expand and restructure their understanding of collision theory and reaction rate.

b. Reaction Rate Factors and Their Applications.

Analysis of students' cognitive structure using the flow map method which includes all cognitive structure variables in the sub-material on reaction rate factors and their applications produces the following data calculations.

The extent variable showed that Student 06, Student 16, and Student 08 each wrote 7 ideas in the Elaborate stage, while Student 33 wrote 8 ideas. These four students produced more ideas than Student 25, who wrote 6 ideas. Student 06's flow map is shown in Figure 7

Table 3. Analysis of Cognitive Structure of Sub-Material Factors Influencing Reaction Rate

No	Learning Stages	Variables	Student 25	Student 06	Student 16	Student 33	Student 08
1.	Elaborate	Extent	6	7	7	8	7
		Richness	9	10	9	9	7
		Integration	9/(6+9) = 0,6	10/(7+10) = 0,59	9/(7+9)= 0,56	9/(8+9) = 0,53	7/(7+7) = 0,5
		Misconceptions	1	0	2	2	2
		Information retrival rate	2/180 = 0,01	4/180 = 0,02	4/180 = 0,02	5/180 = 0,03	4/180 = 0,02
		Flexibilty	6-2 = 4	7-4 = 3	7-4 = 3	8-5= 3	7-4 = 3
2.	Explain	Extent	7	9	8	8	7
		Richness	11	14	10	10	8
		Integration	11/(7+11) = 0,61	14/(9+14) = 0,61	10/(8+10) = 0,56	10/(8+10) = 0,55	8/(7+8) = 0,53
		Misconceptions	0	0	1	2	1
		Information retrival rate	4/180 = 0,02	5/180 = 0,03	5/180 = 0,03	4/180 = 0,02	4/180 = 0,02
		Flexibilty	7-3 = 4	9-5 = 4	8-5 = 3	8-4 = 4	7-4 = 3

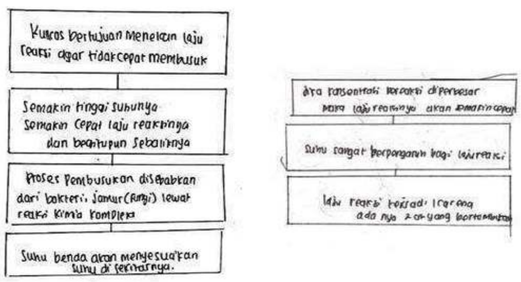


Figure 7. Student 06, elaborate stage flow map

Student 06 wrote down 7 ideas in total on flow map at the stage elaborate. Students have been able to relate the case study video about the refrigerator to the material on reaction rate factors, namely temperature. This shows that student 06 reflects on initial knowledge with the information obtained. Because students have passed the stage to engage, explore, and e-search.

The richness variable also increased in several students, particularly Student 25, Student 06, and Student 16. Student 16 wrote 7 ideas and 9 repeated-link arrows in the Elaborate stage, then increased to 8 ideas and 10 repeated-link arrows in the Explain stage. This increase indicates that the student developed stronger relationships among concepts after group discussion and explanation activities. The integration variable showed that Student 06 had the highest integration value in the Explain stage, with a value of 14/(9+14) = 0.61. This result indicates that Student 06 had the most interconnected conceptual structure among the five students analyzed in this sub-material.

The misconception variable showed a decreasing trend from the Elaborate stage to the Explain stage. Student 08 still showed one misconception in the Explain stage, as presented in Figure 8.

Figure 8. Student 08, flow map stage explain

Student 08 wrote that the more contact surfaces there are, the faster or greater the reaction rate will be. This idea needs refinement because smaller particle size increases surface area, allowing more frequent collisions and causing the reaction to proceed faster [23]. This misconception indicates that students may understand the general relationship between surface area and reaction rate but still need clearer conceptual explanation about particle size, contact area, and collision frequency. The information retrieval rate variable showed that Student 06 expressed ideas more quickly than the other four students. This indicates that Student 06 had a relatively stronger ability to retrieve and write conceptual information in flow map form.

The flexibility variable showed that all students added ideas between the Elaborate and Explain stages. Student 25 added four ideas in both stages, while Student 06 and Student 33 increased from three additional ideas in the Elaborate stage to four additional ideas in the Explain stage. This result indicates that E-search, Exchange, and Evaluate activities helped students expand their conceptual understanding of reaction rate factors.

c. Reaction Rate Equation, Reaction Order, and Rate Constant.

The third sub-material analyzed was reaction rate equation, reaction order, and rate constant. This sub-material requires students to connect conceptual understanding with symbolic and mathematical representations. Students' flow maps were examined to identify how they organized ideas related to rate equations, reaction orders, rate constants, and calculation procedures. The comparison between the Elaborate and Explain stages was used to determine whether students' cognitive structures became more integrated after discussion, teacher clarification, and problem-solving activities, as presented in Table 4.

Table 4. Cognitive Structure Analysis of Sub-Material Reaction Rate Equations, Reaction Orders, and Rate Constants

No	Stages	Variables	Student 04	Student 11	Student 03	Student 17	Student 09
1.	Elaborate	Extent	5	7	7	8	8
		Richness	7	9	10	10	12
		Integration	7/(7+5) = 0,58	9/(7+9) = 0,56	10/(7+10) = 0,59	10/(8+10) = 0,56	12/(8+12) = 0,6
		Misconceptions	1	1	1	2	1
		Information retrival rate	5/180 = 0,03	5/180 = 0,03	6/180 = 0,03	5/180 = 0,03	5/180 = 0,03
		Flexibilty	5-5 = 0	7-5 = 2	7-6 = 1	8-5 = 3	8-5 = 3
2.	Explain	Extent	6	10	11	9	8
		Richness	9	13	17	14	13
		Integration	9/(6+9) = 0,6	13/(10+13) = 0,57	17/(11+17) = 0,61	14/(9+14) = 0,61	13/(8+13) = 0,62
		Misconceptions	1	0	0	1	0
		Information retrival rate	5/180 = 0,03	6/180 = 0,03	8/180 = 0,04	5/180 = 0,03	5/180 = 0.03
		Flexibilty	6-5 = 1	10-6 = 4	11-8 = 3	9-5 = 4	8-5 = 3

The extent variable showed that Student 11 and Student 03 each wrote 7 ideas in the Elaborate stage, while Student 17 and Student 09 each wrote 8 ideas. These four students produced more ideas than Student 04, who wrote 5 ideas. Student 11's flow map is shown in Figure 9. Student 11 wrote down 7 ideas in a total flow map at the stage elaborate. Students have been able to understand the concept of rate equations, reaction orders, and rate constants. This shows that students 11 reflect their initial knowledge with the information they have obtained. Because students have passed the stage to engage, explore, and e-search.

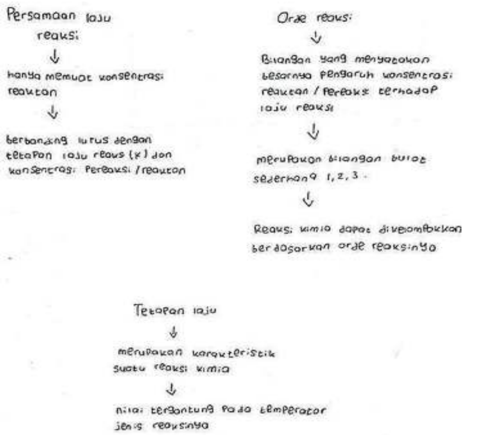


Figure 9. Student 11, flow map stage elaborate

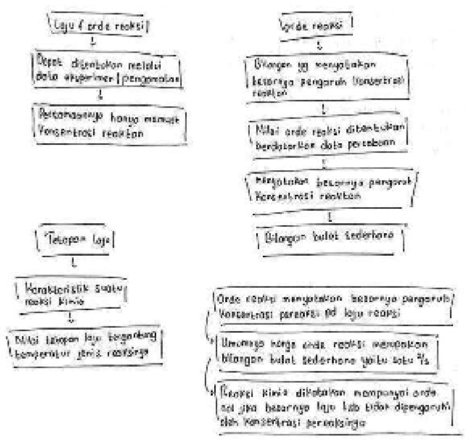


Figure 10. Student 03, flow map stage explain

The richness variable showed an increase in repeated relationships among several students, particularly Student 04, Student 11, Student 03, and Student 17. Student 03 wrote 7 ideas and 10 repeated-link arrows in the Elaborate stage, then increased to 11 ideas and 17 repeated-link arrows in the Explain stage. Student 03's flow map in the Explain stage is shown in Figure 10.

Student 03 organized ideas well in the flow map and showed conceptual development after participating in the 8E Learning Cycle stages. This interpretation was supported by the comprehension test result for question number 5, as shown in Figure 11.

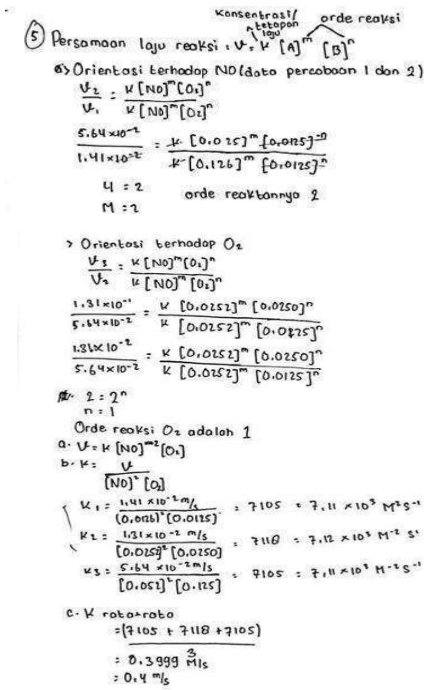


Figure 11. Student 03 Comprehension Test Result

Question number 5 of the comprehension test instrument is a calculation question, students are asked to determine the order, reaction rate equation, rate constant value, and average value of the reaction rate constant. Based on the answers above, student 03 can answer all questions correctly by reflecting on the knowledge gained from the results of discussions with group members and when the teacher explains the example questions, students can digest them well.

The integration variable showed that Student 09 had the highest integration value in the Explain stage, with a value of 13/(8+13) = 0.62. This value indicates that Student 09 produced the most interconnected ideas compared with the other four students in this sub-material. The misconception variable showed that misconceptions tended to decrease in the Explain stage. Student 17 still had one misconception related to reaction order, as shown in Figure 12.

Figure 12. Student 17, flow map in the explain stage

Student 17 showed a misconception by stating that reaction order can be determined directly from the reaction equation. The scientifically appropriate concept is that reaction order cannot be determined from the stoichiometric coefficients of the overall reaction equation but must be determined experimentally [22]. This finding indicates that students may still confuse reaction coefficients with reaction orders when interpreting rate equations.

The information retrieval rate variable showed that Student 03 had the strongest ability to write ideas quickly in flow map form compared with the other four students. This result indicates that Student 03 was able to retrieve and organize information efficiently after the learning process.The flexibility variable showed that all students added ideas from the Elaborate stage to the Explain stage. Student 04 added one idea, Student 11 increased from two to four additional ideas, Student 03 increased from one to three additional ideas, Student 17 increased from three to four additional ideas, and Student 09 consistently added three ideas in both stages. This result shows that students' cognitive structures developed after participating in E-search, Exchange, and Evaluate activities.

Overall, the analysis shows that students' cognitive structures improved during the learning process. The number of ideas and conceptual connections increased, while misconceptions tended to decrease between the Elaborate and Explain stages. Students also showed stronger conceptual organization in collision theory, reaction rate factors, and reaction rate equation topics. These findings indicate that the 8E Learning Cycle model supports the development of students' cognitive structures by encouraging exploration, discussion, reflection, and conceptual integration. The use of flow maps also helped reveal how students organized ideas, connected concepts, and reconstructed their understanding during reaction rate learning [1], [3], [13].

CONCLUSION

This study investigated the development of students' cognitive structures on reaction rate concepts through the implementation of the 8E Learning Cycle model using the flow map method. The findings show that students' cognitive structures improved during the learning process, as indicated by increases in the extent, richness, integration, information retrieval rate, and flexibility variables, along with a decrease in misconceptions between the Elaborate and Explain stages. The results demonstrate that the 8E Learning Cycle model facilitates students in organizing and connecting scientific concepts through exploration, discussion, and reflection. These learning activities support meaningful learning experiences that promote the development of students' conceptual understanding and cognitive structures. Therefore, the 8E Learning Cycle model can be considered an effective instructional approach for promoting deeper conceptual learning in chemistry, particularly in the topic of reaction rates. The use of the flow map method also provides valuable insights for teachers in identifying students' cognitive structures and misconceptions during the learning process.

REFERENCES

[1] Q. Zhou, T. Wang, and Q. Zheng, "Probing high school students' cognitive structures and key areas of learning difficulties on ethanoic acid using the flow map method," *Chemistry Education Research and Practice*, vol. 16, no. 3, pp. 589–602, 2015, doi: https://doi.org/10.1039/C5RP00059A.

[2] R. Garner, *Getting to Got It! Helping Struggling Students Learn How to Learn*. Alexandria, VA, USA: Association for Supervision and Curriculum Development, 2007.

[3] C.-C. Tsai, "Probing students' cognitive structures in science: The use of a flow map method coupled with a meta-listening technique," *Studies in Educational Evaluation*, vol. 27, no. 3, pp. 257–268, 2001, doi: https://doi.org/10.1016/S0191-491X(01)00029-3

[4] I. P. Artayasa, H. Susilo, U. Lestari, and S. E. Indriwati, "The effect of three levels of inquiry on the improvement of science concept understanding of elementary school teacher candidates," *International Journal of Instruction*, vol. 11, no. 2, pp. 235–248, 2018, doi: https://doi.org/10.12973/iji.2018.11216a.

[5] A. N. Cahyo, *Panduan Aplikasi Teori-Teori Belajar Mengajar Teraktual dan Terpopuler*. Yogyakarta, Indonesia: Diva Press, 2013.

[6] T. W. Maduretno, Sarwanto, and W. Sunarno, "Pembelajaran IPA dengan pendekatan saintifik menggunakan model learning cycle dan discovery learning ditinjau dari aktivitas dan motivasi belajar siswa terhadap prestasi belajar," *Jurnal Pendidikan Fisika dan Keilmuan*, vol. 2, no. 1, pp. 1–11, 2016, doi: https://doi.org/10.25273/jpfk.v2i1.19.

[7] E. Kaya and O. Geban, "Facilitating conceptual change in rate of reaction concepts using conceptual change oriented instruction," *Education and Science*, vol. 37, no. 163, pp. 216–225, 2012, doi: https://doi.org/10.15390/ES.2012.1014

[8] K. S. Taber, "Building the structural concepts of chemistry: Some considerations from educational research," *Chemistry Education Research and Practice*, vol. 2, no. 2, pp. 123–158, 2001, doi: https://doi.org/10.1039/B1RP90014E

[9] S. I. Y. Mersa, S. Sidauruk, and M. E. Anggraeni, "Analysis of students'

difficulties in understanding the concept of reaction rate (systematic review)," *Jurnal Ilmiah Kanderang Tingang*, vol. 15, no. 1, pp. 215–225, Jun. 2024, doi: https://doi.org/10.37304/jikt.v15i1.228

[10] M. J. Ahiakwo and C. Q. Isiguzo, "Students' conceptions and misconceptions in chemical kinetics in Port Harcourt Metropolis of Nigeria," *African Journal of Chemical Education*, vol. 5, no. 2, pp. 112–130, Jul. 2015.

[11] L. A. Lestari, Subandi, and Habiddin, "Identifikasi miskonsepsi siswa pada materi laju reaksi dan perbaikannya menggunakan model pembelajaran Learning Cycle 5E dengan strategi konflik kognitif," *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, vol. 6, no. 6, pp. 888–894, 2021, doi: https://doi.org/10.17977/jptpp.v6i6.14876

[12] J. Jusniar, Effendy, E. Budiasih, and Sutrisno, "Misconceptions in rate of reaction and their impact on misconceptions in chemical equilibrium," *European Journal of Educational Research*, vol. 9, no. 4, pp. 1405–1423, 2020, doi: https://doi.org/10.12973/eu-jer.9.4.1405

[13] O. R. Anderson and O. J. Demetrius, "A flow-map method of representing cognitive structure based on respondents' narrative using science content," *Journal of Research in Science Teaching*, vol. 30, no. 8, pp. 953–969, 1993, doi: https://doi.org/10.1002/tea.3660300811

[14] P. J. Bischoff and O. R. Anderson, "Development of knowledge frameworks and higher-order cognitive operations among secondary school students," *Journal of Biological Education*, vol. 35, no. 3, pp. 113–120, 2001, doi: https://doi.org/10.1080/00219266.2000.9655747

[15] H. S. Dhindsa and O. R. Anderson, "Using a conceptual-change approach to help preservice science teachers reorganize their knowledge structures for constructivist teaching," *Journal of Science Teacher Education*, vol. 15, no. 1, pp. 63–85, 2004, doi: https://doi.org/10.1023/B:JSTE.0000031463.56206.a5

[16] M. B. Miles and A. M. Huberman, *Qualitative Data Analysis: An Expanded Sourcebook*, 2nd ed. Thousand Oaks, CA, USA: Sage Publications, 1994.

[17] Y. S. Lincoln and E. G. Guba, *Naturalistic Inquiry*. Newbury Park, CA, USA: Sage Publications, 1985.

[18] N. Balta and H. Sarac, "The effect of 7E Learning Cycle on learning in science teaching: A meta-analysis study," *European Journal of Educational Research*, vol. 5, no. 2, pp. 61–72, 2016, doi: https://doi.org/10.12973/eu-jer.5.2.61.

[19] A. Eisenkraft, "Expanding the 5E model," *The Science Teacher*, vol. 70, no. 6, pp. 56–59, Sep. 2003. [Online]. Available: https://eric.ed.gov/?id=EJ677483

[20] E. Mahardika, Nurbaity, A. Ridwan, and Y. Rahmawati, "Analisis struktur kognitif siswa dengan metode flowmap dalam materi asam basa menggunakan model Learning Cycle 8E," *EduChemia: Jurnal Kimia dan Pendidikan*, vol. 3, no. 1, pp. 51–65, 2018. [Online]. Available: https://jurnal.untirta.ac.id/index.php/EduChemia/article/view/1849

[21] R. Michalisková, Z. Haláková, and M. Prokša, "Concept of chemical reaction in chemistry textbooks," *Chemistry Teacher International*, vol. 1, no. 2, 2019, doi: https://doi.org/10.1515/cti-2018-0027.

[22] R. Chang, *General Chemistry: The Essential Concepts*, 5th ed. New York, NY, USA: McGraw-Hill Higher Education, 2008.

[23] M. S. Silberberg, *Chemistry: The Molecular Nature of Matter and Change*, 5th ed. New York, NY, USA: McGraw-Hill, 2009.