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Boosting Critical Thinking Skills: Applying the Dilemma Stories Approach with the 5E Learning Cycle in Buffer Subject Education

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ABSTRACT

This study explores the impact of the Dilemmas approach, rooted in transformative learning, on enhancing critical thinking skills in buffer chemistry subjects among high school students. Employing a mixed-methods design and purposive sampling, the research involved 34 eleventh-grade students from SMAN 1 Surakarta. The implementation of dilemma stories integrated with a 5E learning cycle was scrutinized using various data collection methods, including observations, student reflective journals, pretest-posttest assessments, the Constructivist Chemistry Values Learning Environment Survey (CCVLES), and interviews. Observations assessed the application of the dilemma stories and the 5E learning cycle. Pretest-posttest evaluations measured changes in students' critical thinking abilities, while reflective journals and CCVLES questionnaires captured students' perceptions of their critical thinking skills and their learning experiences. Interviews were conducted to validate the findings from the tests, journals, and questionnaires. Data analysis involved reduction, display, and conclusion-drawing techniques. The findings suggest that the Dilemmas approach significantly fosters students' ability to think critically and apply chemical concepts practically. This was evidenced by students' analyses of dilemma stories and responses in interviews, CCVLES questionnaires, and reflective journals, indicating a deeper engagement with and understanding of the subject matter through this innovative learning strategy.

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1. INTRODUCTION

The goals of education are constantly changing as the 21st century unfolds. Contemporary education goes beyond just imparting facts and figures; it places a premium on helping students develop critical thinking skills appropriate to the modern world. In order to appropriately educate students for future difficulties, it is vital that educational systems incorporate these abilities into their curricula. These abilities are critical for creating competent employees and encouraging a love of learning and growth in one's own abilities throughout one's life (Lovat, Toomey, & Clement, 2010). Schools have a responsibility to help students develop all of these important abilities, but critical thinking stands out as particularly important. Students are able to make well-informed decisions when they possess critical thinking skills, which are defined by Facione (2011) as reasoning, reflecting, and constructive evaluation.

Critical thinking skills are considered essential skills and necessary in the learning process because, through these skills, students are invited to learn through discovery. Critical thinking is one of the aspects of thinking that help people overcome difficulties and facilitate access to information in life (Ghazivakili et al., 2014). Critical thinking skills can be formed through changes in the learning process called transformative learning.

Transformative learning is the learning concept that can produce changes in individuals related to how an individual understands and interprets the reality and experiences of his life (Rosmilawati, 2017). Transformative learning was first introduced by Mezirow in 1978. Transformative learning is a process that describes how learners transform a habit of their mind by redefining a problem and examining their assumptions, content, or process for problem-solving (Mezirow, 2012). This theory helps explain how adults change the way they interpret their world.

Transformative learning theory is considered unique and mature because it is based on human communication, where learning is a process of using prior understanding to interpret or revise one's experience to guide future action (Jerković, 2012). Transformative learning objectives focus on changes in students which will affect values, attitudes, and behaviors. Transformative learning involves habits, thinking, and meaningful perspective, which leads to perspective transformation. In addition, transformative learning has become a paradigm because it has explained many unanswered questions about adult learning and created its own dedicated group of practitioners (Kitchenham, 2008). One approach that can be applied in the transformative learning process is the dilemma story approach.

A dilemma story approach is an approach that is related to everyday life and prioritizes contextual learning, which is presented through stories that raise dilemmas for students (Winarti, Nahraniah, & Iriani, 2021). The purpose of this approach is for students to have a deep conceptual understanding and problem-solving skills and to determine decisions from dilemma stories given through group discussions. By providing problems that can cause emotions and dilemmas, students are trained to think critically and solve problems in everyday life. The dilemma story approach does not aim replace content-based science education, but it aims to increase its quality by adding value to students' learning (Rahmawati, Nurbaity, & Marheni, 2014). Dilemma stories help the teacher to increase students' critical thinking and collaborative decision-making (Taylor, 2009). There are some examples of dilemmas that have developed in several countries, such as climate change, nuclear power, acidification, and rice fish dilemma (Taylor R, 2007).

One of the subjects that are considered difficult at the high school level is chemistry. Chemistry is a branch of science that examines related materials in terms of properties, changes in energy, and the structure of a material (Demircioglu & Ayas, 2005). Generally, chemistry is taught in high school starting from grade 10. Chemical concepts are concrete, abstract, and procedural so they require a good understanding. One of the topics discussed in chemistry is the buffer concept. Buffer is a solution that can keep pH values when little acid or base is added. If strong acid is added to the buffer, H^+ ions from acid will be neutralized by conjugate ions so the pH value is constant (Kusumaningrum, Ashadi, & Indriyanti, 2017). Besides that, if a strong base of in small size is added to an acidic buffer, the OH^- ion from the base will combine with the H^+ ion from an acidic buffer

(Fox, Greenberg, & Trookman, 2015). Calculating the pH of a buffer used the Henderson-Hasselbalch equation, that is: pH =pKa + log $\frac{\{conjugate\}}{[weak\ acid]}$ (De Oliveira, 2020).

Many students assume that buffer is one of the difficult concepts in chemistry (Orgill & Sutherland, 2008). The buffer solution concept relates to other concepts such as acid/base chemistry, chemical equilibrium, chemical reactions, the particulate nature of matter, stoichiometry, and solution chemistry (Mutlu & Sesen, 2016). Most of these topics are not only interrelated but also fundamental to understanding the nature of chemistry, so that will create problems for students if the students do not understand the chemistry topics well (Salame, Ramirez, Nikolic, & Krauss, 2022). Students encounter challenges when studying buffer solutions because they depend on the memorization of formulas and the many steps involved in buffer solutions (Salame et al., 2022). However, the buffer concept is related to everyday chemical reactions. Therefore, students need to be active and enthusiastic in learning to understand the concept more deeply (Septian, Susilaningsih, & Sumarti, 2020). The buffer concept is related to the environment and its environmental problems (Winarti et al., 2021). Hence, the buffer concepts can be developed into chemical concepts that can change students' thoughts, emotions, and attitudes. The involvement and activity of students in studying the buffer concepts can determine the level of students' understanding of the buffer concept. Therefore, a learning model involving the student's activity is required. The learning model that can invite students to be involved in learning activities at school is the 5E Learning cycle.

The 5E Learning cycle model is a learning model that has student-centered learning characteristics with five phases of learning, namely engagement (engaging students' interest and curiosity), exploration (finding out information), explanation (concept application), elaboration, and evaluation (Bilgin & Coşkun, 2013). By using learning phases such as the 5E Learning Cycle, students can be active in learning so that the expected learning skills and objectives can be achieved, including critical thinking skills (Runisah, Herman, T., and Dahlan, 2017). Students can play an active role in studying and getting understandable concepts besides the teacher's information (Fauzi & Mustadi, 2019). Previous research has proven that the 5E learning cycle model can improve critical thinking skills compared to conventional learning models on solubility materials (Nurhayati, Rahayu, & Yahmin, 2016). In addition, this learning model can improve students' thinking skills and understanding of buffer concepts. It is shown by the percentage of critical thinking skills in the first cycle of 61.15% and the second cycle of 76.01% (Maulidia, Hamid, & Sholahuddin, 2019). This research shows that the 5E learning cycle model can be used to improve the critical thinking skills of high school students in chemistry subject.

The issues identified underscore the necessity for implementing transformative learning through the 5E Learning Cycle model, integrated with a dilemma stories approach, to enhance critical thinking skills in the buffer subject. This study investigates the effectiveness of the dilemma stories approach underpinned by transformative learning, combined with the 5E learning model, to enrich the existing cognitive-focused buffer subject curriculum. By adopting this method, students are expected not only to grasp the concept of buffers comprehensively but also to apply these concepts in real-life scenarios, thereby transforming their mindsets and perspectives. Ultimately, this approach aims to significantly improve students' critical thinking abilities, demonstrating the practical benefits of transformative learning in an educational setting.

2. METHODS

The research was conducted for six months, from November 2021 to May 2022, at SMAN 1 Surakarta. This study used a mixed method that combines qualitative and quantitative research using an explanatory sequential design. Quantitative data were obtained from pretest and post-test scores and a critical thinking skills questionnaire, while qualitative data were obtained from observations and reflective learning journals used to explore, prove, and expand the results of quantitative research. The quantitative research design chosen was a pre-experimental one-group pretest-post-test design,

which involved giving a test before and after the research to one group. Then, the qualitative research chose descriptive qualitative research by collecting data from observation sheets, learning reflective journals, and interview instruments.

The sampling technique chosen was the purposive sampling technique using specific considerations. The consideration was classes taught by researchers so that researchers could find out the conditions of class learning. In addition, another important consideration was the class had already received the buffer concept.

Table 1. One-Group Pretest-Posttest Design

Pretest	Treatment	Postest
O_1	X	O_2

Determination of N-gain using the equation:

$$\text{N-gain (g)} = \frac{postes - pretes}{Maximum\ scors - pretes}$$

The N-gain classification is presented in Table 2.

Table 2. N-gain Classification

No.	Classification	Category
1.	g≥0,7	High increase
2.	0,3≤g≤0,7	Medium increase
3.	g<0,3	Low increase
4.	g = 0,00	Constant
5.	-1,00<g<0,00	Decrease

(Hake, 1999)

The qualitative data analysis technique uses Miles and Huberman's data analysis technique, which includes three research stages, they are data reduction which aims to summarize, select the main things, and focus on the important things to look for patterns; data display to facilitate the presentation of data between quantitative and qualitative results; Conclusion whose the results are combined with the results of quantitative research (Miles & Huberman, 2005).

3. FINDINGS AND DISCUSSION

The implementation results of the dilemma stories approach by using 5E Learning cycle at SMA N 1 Surakarta can be seen in the form of interviews, observations, reflective journal data, and CCVLES questionnaires filled by students and strengthened by the results of the pretest-posttest as the quantitative data. Observations to determine the implementation of the 5E Learning Cycle model with the Dilemmas Stories Approach by students and teachers show that students and teachers can carry out learning with the dilemma stories approach through 5E Learning cycle. Observations are arranged based on indicators of critical thinking skills, according to Facione (2011), which are adapted to the 5E Learning cycle syntax and the dilemmas stories approach. Observations were carried out by two observers using an observation sheet in the form of a checklist so that observers only needed to mark certain scores when observing. Each activity uses the lowest score of 1 to the highest is 5. Observation data are presented in Table 3.

Table 3. The Implementation Results of the 5E Learning Cycle Model with the Dilemma Stories Approach by Students

5E Learning Cycle Syntax	Critical Thinking Skills Indicators	Students' activity	Average value	Categorization
Engangement	Interpretation	Respond to teacher questions	5	Very good
		Asking question about the topic of discussion.	4,42	Good
Exploration	Interpretation	Identify the problem	4,58	Very good
	Analysis	Collecting information/data	4,58	Very good
		Connecting information with stories	4,67	Very good
	Evaluation	Reflecting so that a dilemma arises	4,67	Very good
	Inference	Making decisions in the group	5	Very good
Explanation	Explanation	Reporting and submitting answers to the cases given	4,75	Very good
Elaboration	Inference	Make conclusions with the teacher	4,25	Good
Evaluation	Self-Regulation	Complete the posttest/ assessment(evaluation) given by the teacher	5	Very good

Table 3 shows that students are good at asking questions about the topic of dilemma stories. This is evidenced by the enthusiasm of students in solving dilemma stories and they ask if there are things that is not yet known. At this phase, the critical thinking skills indicator of interpretation shows that students can understand and express the meaning of the problem and what is being asked in the question clearly and precisely. Then, at the exploration phase, it shows that each group is very good at identifying problems, collecting information/data, connecting information with the stories at hand, reflecting on themselves so that dilemmas arise, and ending with making decisions in the group.

Table 4. The Implementation Results of the 5E Learning Cycle Model with the Dilemma Stories Approach by Teacher

Syntax of 5E Learning Cycle	Teacher's activity	Average value	Categorization
Engangement	Assessing students' prior knowledge through pretest	5	Very good
	Presenting the stimulus	4	Good
	Informing learning activities to the next stage.	4,5	Good
Exploration	Ensuring students collect data/information to solve problems related to dilemma stories	4,25	Good
	Helping students understand concepts as students' considerations in making decisions from dilemma stories	5	Very good
Explanation	Pay attention to students' explanations about the dilemma story	4,75	Very good
Elaboration	Give a more detailed and broad explanation	4,58	Very good
	Making conclusions from the dilemma story with students	4,5	Good
Evaluation	Give a post-test/assessment at the end of the lesson	4,5	Good

In the exploration phase, the teacher ensures students collect data/information to solve problems related to the dilemma story well. In addition, at the exploration phase, the teacher helps students understand the questions on the reinforcement material concept sheet and relates the

concepts to the phenomena that occur in the dilemma story so that students are more interested and aware that chemistry is close to everyday life. Through learning chemistry, especially the buffer solutions concept, students can analyze problems in everyday life contained in dilemma stories with scientific and logical reasons. This makes learning through the 5E Learning Cycle model with a dilemma story approach more meaningful. Meaningful learning can see how the subject matter delivered by the teacher can create a relationship between ideas, cognition, information and reality.

The indicators assessed from the research instrument include feelings about dilemma stories, teacher support, critical thinking skills, and the application of chemistry in life/contextual chemistry. The explanation of each indicator is explained as follows:

3.1. The Feelings of Dilemma

The feelings about the dilemma story include whether they are interested and enjoying the dilemma stories and whether this dilemma story is a waste of time or not. Based on the reflective journal, the smoking dilemma story and the using detergent are interesting. The results of the CCVLES questionnaire also prove that as much as 47% of students agree with the statement that they are very interested in the dilemma story, and 53% of students agree that they are happy with the dilemma stories. Besides that, 50% of students strongly disagree that the dilemma stories are a wasting time.

The dilemma stories about smoking and using detergent selected in this buffer lesson can attract students' attention because they think these stories are related to daily life's problems and the studied buffer concepts. In addition, learning by using dilemma stories is unique and different from the cases usually done in learning chemistry. Students also argue that even though the dilemmas stories talk about simple things, the stories can still raise debate and dilemmas among the students. They think that they can still learn the buffer concepts through dilemmas stories. Students feel that the curiosity that arises at the beginning of learning must be completed thoroughly before going home. The results of the CCVLES questionnaire, reflective journal, and interviews showed that students are interested and enjoy learning by using dilemma stories.

"It is fascinating because the material conveyed by the teacher can train us to think critically on interesting topics that are closely related to the life around us."
(Reflective Journal of students 4, April 25, 2022, the smoking dilemma stories)
"In my opinion, the story of the dilemma is quite interesting. I think that learning from daily problems is quite important, easier to understand concepts and we know "what is the use of this material?". Maybe, it will be good if there is a book that contains the dilemmas stories. At least, we can find solution and solve the problems of the dilemma stories when we have vacant time. I think the dilemmas stories not only help students to understand subject, but also trigger creativity or innovation."
(Student Interview 3, May 9 2022, the dilemma story about using detergent)
"Interesting. In my opinion, that's very interesting. Because there are rare cases that can be debated. Debate is usually about an issue. Well, those issues are usually high-level ones, such as politics. However, this is really a case around us that unexpectedly can become an exciting debate, which generates many points of view. That's rare, isn't it? So really just about cigarettes and the material of the buffer requires really critical considerations, how come ? Wow, what's the middle way? So, we are really interested in studying that. I really need to know how the final answer will be in order to be able to go home."
(Student Interview 26, May 9 2022, the smoking dilemma story)

Figure 1. The Interview Excerpts and Reflective Journals Regarding Students' Interest in Dilemma Stories

The stories presented are easy to understand. Interesting illustrations support the stories at the explanation and elaboration phases. Students are motivated to learn more about the buffer concepts through dilemma stories because students must first understand the buffer concept to discover a phenomenon that occurs in the dilemma story. In solving the dilemma story, students also feel challenged to think critically about the overcome of the problem in the dilemma story.

"Yes, because it is presented with an interesting animation when presented. In addition, the stories presented are also easy to understand."
(Reflective Journal of students 12, April 25 2022, the smoking dilemma stories)
"Dilemma stories spur us to think critically in preparation for facing events like those in dilemma stories."
(Journal of Reflective Students 23, April 25, 2022, the dilemma story about using a detergent)
"The dilemma story motivates students to learn buffer concept that is relevant to everyday life problems. We can provide solutions to these problems by studying the buffer concept."
(Reflective Journal of students 3, April 25, 2022, the dilemma story about using a detergent)
"Through dilemma stories students can analyze problems and think critically about a problem"
(Reflective Journal of students 33, April 25, 2022, the smoking dilemma stories)

Figure 2. The Reflective Journal Excerpts Related to Dilemma Stories can Motivate Students in Learning

Students explain why dilemma stories are not a waste of time. Students consider that the main point of learning using the dilemma stories is that they want to learn that chemistry is close to daily life. In addition, as long as what is learned is useful for his life, it cannot be called in vain. Science is broad, so it is related to calculations, the scientific context and how the knowledge obtained in class can be used to solve problems or cases that occur in everyday life. The other students say they could get entertainment and subject matter through dilemma stories. For students who typically learn visually, learning through this dilemma story can help them understand the buffer material and is interesting to learn.

"It's not a waste of time because the initial purpose/essence of learning this dilemma is to teach chemistry, which is closely related to everyday life. Hence, learning it is closely related to everyday life and can be more useful for us. So, as long as there are benefits, why do we call it a waste of time? It's cool! It's supposed to be an icebreaking. Interesting."
(Student Interview 4, May 9 2022, the smoking dilemma stories)
"It's not a waste of time because the dilemma story is shown to teach us how to deal with the same events in everyday life. And it can also train critical thinking. It's interesting because it's challenging so you have to think harder."
(Student Interview 23, May 9, 2022, the dilemma story about using a detergent)
"I think the dilemma about using detergent is fascinating to discuss because the problem is very closely related to our daily lives. The dilemma stories do not waste time because the story is fascinating. Story problems are closely related to daily life. Moreover, the one about cigarettes is no less interesting."
(Student Interview 11, May 9 2022, the dilemma story about using a detergent)
"In my opinion, the dilemma story is not a waste of time. When I read the dilemma story, apart from being entertainment, I also feel like I have learned material. Because I am a typical person whose learning must be visual, and I have to be interested before studying something. So, if I just read the material "Ouch, this is confusing, I will skip it...". Even though we have a long discussion, it is effective because we have to understand the case of dilemma story and the buffer concept in order to solve the dilemma story."
(Student Interview 26, May 9 2022, the smoking dilemma story)

Figure 3. The Interview Excerpts and Related Reflective Journals about whether Dilemma Stories a Waste of Time

3.2. Teacher Support

The implementation of the dilemma stories approach requires the teacher's active as a facilitator and motivator for students in making decisions. The results of the CCVLES questionnaire stated that 62% of students strongly agree if the teacher supports their students to participate in learning actively, 76% of students strongly agree if the teacher allows students to express their views, 62% of students also strongly agree if the teacher helps them to accept different opinions. Based on observation, students ask the teacher actively about dilemma stories learning, especially during the exploration phase. The teacher answers the students' questions and actively walks around to help students in their groups.

The reflective journal and student interviews showed that the teacher helps students understand the problems contained in the dilemma stories and make decisions based on the analysis

on the concept strengthening sheet. Therefore, students can understand and interpret the relationship between dilemma stories and buffer concept strengthening sheets. It shows that the teacher can be a facilitator during the learning process. The teacher's role during the dilemma stories learning as a facilitator is needed because the teacher has to help students understand stories and analysis the relationship between the buffer material and the dilemma stories. In addition, teachers also play a role in inviting students to think critically and train creativity so that teaching and learning activities can be much more meaningful (Demircioglu & Ayas, 2005).

"The teacher helps the group by approaching groups one by one and asking whether they have a problem and helping if we have problem."
(Reflective Journal of students 34, April 25, 2022, the smoking dilemma story)
"The teacher helps us. For example, she helps/tells reactions if we do not know it. I was confused at first. How can it be connected to the buffer concept? So, we can understand buffer concept to solve the problem in the dilemma stories."
(Student Interview 4, May 9 2022, the smoking dilemma story)
"The teacher's role when learning by using dilemma stories is very helpful in explaining and solving existing problems. An example is when students do not understand the existing problems, the teacher will immediately explain in detail so that they can make students really understand."
(Student Interview 11, May 9 2022, the dilemma story about using a detergent)
"The teacher really helps me and the group members in understanding the problems presented in the dilemma story."
(Reflective Journal of students 11, April 25 2022, the dilemma story about using a detergent)

Figure 4. Interview Excerpts and Reflective Journals Regarding the Role of Teachers in the Exploration Phase

During the explanation phase, the teacher guides the discussion and advises noisy students to respect students who are expressing opinions. The teacher provides a more detailed explanation at the elaboration phase, delivers the concluding activity so that students get the main concepts studied. The interviews and reflective journals show the same thing. The teacher reinforces the concept at the elaboration phase, which can answer students' curiosity, the teacher also acts as a moderator and mediator. Therefore, when they have a different opinion, the teacher can reinforce why the decision was chosen. Thus, the dilemma stories approach can indirectly train students' attitudes toward respecting opinions.

"When our group have difficulties, the teacher helps us. The teacher also helps answer what the students ask. Of course, the answers given made us think critically so that we could solve the dilemma story. The teacher explains the best way or answer to the dilemma story at the end of the lesson.
(Reflective Journal of students 2, April 25, 2022, the smoking dilemma story)
"The teacher was really helpful from the start lesson. In the beginning, we review a little concepts. Then, we are given the dilemma stories. At the first, we are still confused. However, in the end, the teacher was really guided us on how to solve it step by step. Finally, all of problem was answered with such a detailed explanation. We understand the conclusion that the is given by teacher. Hence, at the end of the lesson, we are really attracted to the teacher because the teacher's role is important to provide more understanding and provide conclusions from what discuss."
(Student Interview 26, May 9 2022, the smoking dilemma story)
"In learning dilemma stories, students get more roles. Students can assess and compare the results of their discussions through the teacher as a moderator. In this lesson, students are free to express their opinions. When exchanging opinions, teachers listen carefully and respect differences of opinion among students.
(Student Interview 3, May 9, 2022, the dilemma story about using a detergent)
"Yesterday there was a discussion session that can be refuted. If there is an addition from a friend who has the same dilemma story, why is it not accepted? We appreciate and accept all forms of opinion. So, everyone's opinion was accepted. I agree that all opinions are accepted because people's views are different. Because A is also true, B is also true."
(Student Interview 4, May 9 2022, the smoking dilemma story)

Figure 5. Excerpts of Interviews and Reflective Journals regarding the teacher's role in the Explanation and Elaboration Phase

During the learning process, the teacher invites students to participate actively in solving the dilemma stories. Therefore, there is no domination in the group by certain students. The aim is for the students will understand the buffer concept and reflect on their ideas. The buffer concept is a concept that discusses many reactions in daily life. The buffer concept requires active and enthusiastic students during the learning process. To provide a chance for students to learn actively,

the 5E Learning Cycle model is appropriate to be used and combined with the story dilemma approach. It strengthens the theory that the 5E learning cycle model is a student-centered learning model with five learning phases, including interest generation, exploration, explanation, elaboration, and evaluation.

The students are active in their groups to solve dilemma stories associated with the buffer concepts during the learning process. The students actively discuss in their groups. When they decide on something, students give their respective opinions regarding the advantages and disadvantages when the solution is taken. Based on the interview results, students could be actively involved because students feel challenged to solve dilemma stories. Less active students join to participate in solving the dilemma stories after hearing the commotion and debate. To complete and make decisions, students must first understand the concept. The activeness of students during the discussion process to solve the problems in this dilemma story can encourage students to improve critical thinking skills because students must analyze the advantages and disadvantages of the arguments put forward by each group member before making a decision.

"Because there is a debate, my group became active, like the 'how can this be?. What is your response, what are your considerations, how can this be?". However, it makes us have to think critically and in detail. When there is a debate, everyone contributes. Thus, those at the beginning who don't want to listen will say, "What's the problem which makes all of you debate?". In the end, they join to listen and discuss it. In fact, if we want to participate in the discussion, we must understand the concept."
(Student Interview 23, May 9 2022, the smoking dilemma story)
"We discussed in groups to make a decision. In the dilemma story, there are several parts and we divide them to be discussed specifically. Because each part of the dilemma story is discussed in detail, it is possible for everyone to work in small groups. After discussing, we discussed it again with all group members. Each part has its own solution."
(Student Interview 3, May 9 2022, the dilemma story about using a detergent)

Figure 6. Excerpts of Student Interviews Regarding the Implementation of Discussions at the Exploration Phase

3.3 Critical Thinking

The Implementation of the dilemma stories approach can invite students to make decisions regarding the dilemma story. Students who feel they have ideas and thoughts when making decisions experience critical thinking conditions (Elfrida, Hadinugrahaningsih, & Rahmawati, 2017). The implications of the dilemma stories approach through the 5E Learning Cycle model can be seen based on the results of class observation sheets, reflective journals, CCVLES questionnaires, student interviews, group decisions on dilemma stories, and pretest-posttest as quantitative scores. All data are analyzed to determine critical thinking skills.

Students reflect on their ideas. Then, students discuss it in groups to decide on the dilemma story presented. In addition, ideas that are combined with students' knowledge are needed when making decisions. Therefore, students need to figure out additional information and understand the concept of a buffer solution to make their decisions logical and scientific. It is relevant to the purpose of the dilemma stories approach that students have a deep conceptual understanding and the ability to solve problems and decide on dilemma stories through group discussions. Students who think about their ideas show that critical thinking skills can develop well. It is relevant to Facione's definition of critical thinking which are thinking logically, reflecting, and productively to assess something so they can make the right decisions.

I can reflect on my ideas. Through my knowledge, I try to solve the dilemma story while continuing to increase my knowledge. When solving a dilemma story must be based on a strong theory. Thus, we will automatically find out more related theories before solving the dilemma story."
(Journal of Reflective Students 23, April 25, 2022, the dilemma story about using a detergent)
"I have to reflect on my ideas because there are many considerations to decide. By reflecting on our ideas, we can get a conclusion/decision on the answer to the dilemma."
(Reflective Journal of students 14, April 25, 2022, the smoking dilemma story)

Figure 7. Excerpts of Reflective Journal Regarding the Students' reflection

The observations prove that students can follow each syntax of the 5E Learning Cycle model well. This learning positively impacts indicators of critical thinking skills, proved by students finding solutions from dilemma stories. Then, the students analyze the problem well, evidenced by their skills to relate the information to the stories they faced. The observations show that students can assess themselves during the evaluation phase so that a dilemma arises. At the explanation phase, the observation reveals that the students can explain the consideration of the decisions chosen. Students and teachers make conclusions well so that the inference indicator can be achieved very well.

(a) (b)

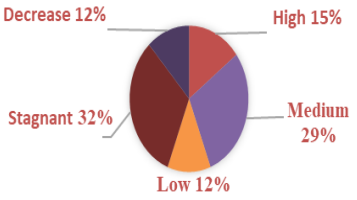
Figure 8. Learning Activities at (a) the Exploration Phase (b) Explanation and Elaboration phase

The results of the CCVLES questionnaire confirm the results of observations and reflective journals. That questionnaire shows that 59% of students agree that they think critically about their ideas, 71% agree that they analyze ideas to solve dilemma stories at the beginning of learning, and 53% of students agree that they are more precise about their ideas after discussing together the dilemma stories.

Increased scores dominate the pretest-posttest results scores. The pretest-posttest results are analyzed using SPSS statistic 23 and the Shapiro-Wilk normality test. The normality test shows a significance value of 0.165, which means the value is more than 0.05. Therefore, the data in this study are normally distributed and could be analyzed with the N-gain score.

Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
NGain_Persen	Experiment	.168	32	.022	.952	32	.165



(a) (b)

Figure 9. The pretest-posttest results (a) the normality test (b) the N-gain Classification

Figure 9 shows that more students experienced an increase in critical thinking skills than those who were stagnant or decreased. The analysis shows that as many 15% students are in the high improvement category, 29% are in the medium improvement category, and 12% are in the low improvement category. As many 12% included decrease categorization and 32% included stagnant categorization. The researcher tried to find out the reason why some of students experienced stagnant and decrease their score by doing interview with some of them. They answered that they have another reason which made they do not focus on their posttest, for the example because of organization and internet connection. The results of the N-gain classification are shown in Figure 9 (b).

Based on the pretest-posttest results show that the purpose of this study to improve critical thinking skills has been achieved. The pretest-posttest is used in this study to assess critical thinking skills because critical thinking skills involve cognitive aspects and encourage students to reflect on

problems and ideas. Critical thinking skills can be measured directly by observing how students' activities and knowledge answer questions and provide reasonable and appropriate reasons. In addition, the pretest-posttest on the dilemma story approach strengthens the previous theory. The dilemma story approach not only teaches students to make decisions but also to understand the material learned and relate it to the dilemma (Rahmawati, Taylor, Taylor, & Koul, 2021). One of groups' explanations is presented in Figures 10 and 11.

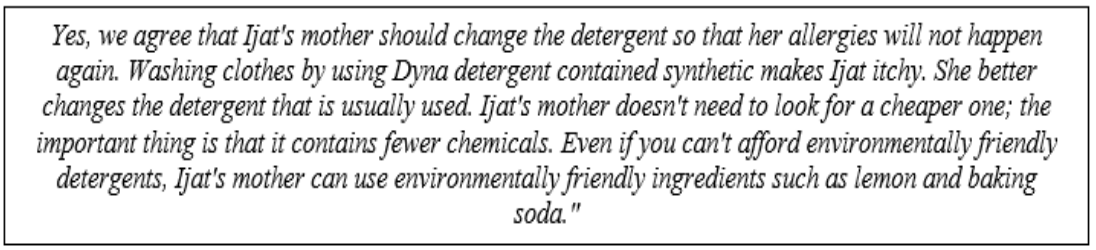

Yes, we agree that Ijat's mother should change the detergent so that her allergies will not happen again. Washing clothes by using Dyna detergent contained synthetic makes Ijat itchy. She better changes the detergent that is usually used. Ijat's mother doesn't need to look for a cheaper one; the important thing is that it contains fewer chemicals. Even if you can't afford environmentally friendly detergents, Ijat's mother can use environmentally friendly ingredients such as lemon and baking soda."

Figure 10. Excerpts Explanation of Group 4 about The Dilemma Story Using a Detergent

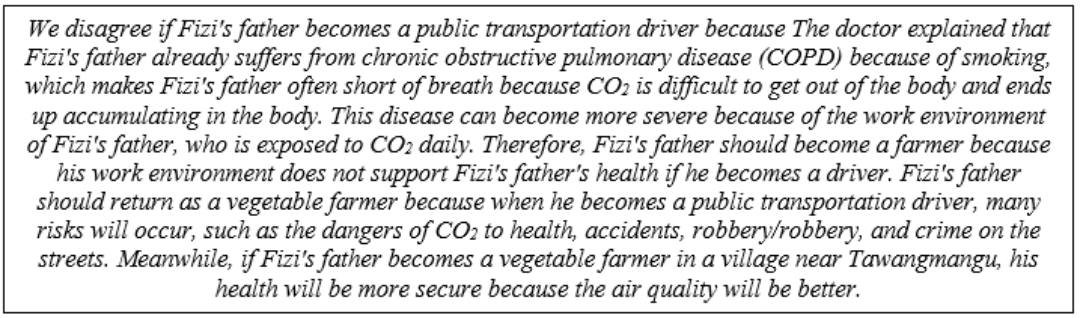

We disagree if Fizi's father becomes a public transportation driver because The doctor explained that Fizi's father already suffers from chronic obstructive pulmonary disease (COPD) because of smoking, which makes Fizi's father often short of breath because CO_2 is difficult to get out of the body and ends up accumulating in the body. This disease can become more severe because of the work environment of Fizi's father, who is exposed to CO_2 daily. Therefore, Fizi's father should become a farmer because his work environment does not support Fizi's father's health if he becomes a driver. Fizi's father should return as a vegetable farmer because when he becomes a public transportation driver, many risks will occur, such as the dangers of CO_2 to health, accidents, robbery/robbery, and crime on the streets. Meanwhile, if Fizi's father becomes a vegetable farmer in a village near Tawangmangu, his health will be more secure because the air quality will be better.

Figure 11. Excerpts Explanation of Group 5 about The Smoking Dilemmas Stories

The 5E Learning Cycle model can improve critical thinking skills because this model is based on the constructivism learning theory. Constructivism learning theory explains that in the learning process, it is necessary to provide opportunities for students to assimilate information through environmental exploration and connect their concepts and information to explain the phenomena that occur. Therefore, they can develop thinking skills and knowledge, including critical thinking skills (Ormrod, 2008). Meanwhile, the dilemma stories approach can improve critical thinking skills because students are trained to make decisions based on their information and chemistry concepts. It shows a match between the learning model and the approach used, so it can be combined to train students' critical thinking skills. The suitability of combining the 5E Learning Cycle model with the dilemma stories approach to improve critical thinking skills can be seen from the dilemma stories indicator and the syntax of the 5E Learning Cycle model which is provided in Table 5.

Table 5. The Matching Point between the 5E Learning Cycle Model and the Dilemma Stories Approach

Aspect	Indicator	Dilemmas stories Approach	5E Learning Cycle Model
Critical Thinking Skills	Interpretation	Students experience dilemmas or disorientation through dilemma stories.	Generating interest through stimulus/problem for students to solve
	-Analysis - Inference	- Examine their self-critical assumptions - Self-examination that brings up feelings of shame	The exploration phase is where students collect information and data to solve problems from the stimulus provided by the teacher.
	Explanation	The change process can be communicated and negotiated with others similarly	The Explanation phase is where students explain their group decisions based on their reflections and references.
	Inference	Acquire knowledge and skills to implement plans	The Elaboration phase is where the teacher reinforces the decisions that have been made by students and what attitudes need to be made in the future

	-Evaluation -Self-Regulation	a. Trying the new role. b. Building confidence in new roles and relationships.	The Evaluation phase is where the teacher provides reflection journals, questionnaires, and post-tests to students to measure students' critical thinking skills.
The learning theory	Constructivisme	The dilemma stories approach is based on constructivism learning theory which makes the learning more meaningful because this approach is associated with the problems of daily life that are presented in the form of dilemma stories.	The learning 5E model is based on constructivism learning theory, making learning more meaningful because students are expected to collect and connect the information obtained with the dilemma stories' problems in the learning syntax.

3.4 Contextual Learning

The dilemma stories approach presents the stories that can lead students to learn to care about the environment, chemicals, and chemical knowledge that can be useful for human life (Winarti et al., 2021). Based on the reflective journal shows that students feel that by learning through this dilemma stories approach, students are more familiar with chemistry in life. The problems presented are also relevant to everyday life, namely smoking and using detergents which often negatively impact health and the environment.

The dilemma story is very relevant to our lives. I have become more aware and understand the application of buffers in daily life. I often see such cases in my neighborhood."
(Reflective Journal of students 26, April 25, 2022, the smoking dilemmas stories)
The dilemma stories are relevant to daily problems because detergent is a material that can be used to wash clothes. Through the buffer material, I understand more about the chemical content in the detergent."
(Reflective Journal of students 8, April 25, 2022, the dilemma story using a detergent)

Figure 12. Excerpt of Reflection Journal on Chemistry in Life

The CCVLES questionnaire designed to know the students' opinions from a constructivist learning environment shows that through the 5E Learning Cycle model with a dilemma stories approach, the students can learn the benefit of chemistry in their life. The CCVLES questionnaire reveals as many as 62% of students strongly agree that chemistry is dangerous for us if we are not wise to chemical substances, and 47% of students strongly agree that they can use chemistry knowledge in their life. The results of the interview also reinforce that through dilemma stories, students can relate the concept of the buffer concept in life. Through the concept of buffer, students can find out phenomena that occur in life so that students have an idea that chemistry can answer problems in life.

"There is a reaction that relate to buffer and life. For the example, why there H_2CO_3 and HCO_3^- is because HCO_3^- (bicarbonate ion) forms a buffer with H_2CO_3 (carbonic acid) to maintain pH condition in our body."
(Student Interview 4, 9 May 2022, the smoking dilemmas stories)
"We can relate the buffer concept to the dilemma stories. For example, as I remember, CO2 increases when eutrophication occurs. The CO_2 reacts with H_2O to produce H^+, which causes acid or decreasing pH. After that, the bicarbonate will catch the H^+ in the pool to keep the pH from decreasing sharply.
(Student Interview 13, 9 May 2022, the dilemma story using a detergent)

Figure 13. Excerpt of the Interview Regarding Buffer Material in Life

The results of student interviews, class observation sheets, reflective journals, the decision of dilemma stories, and pretest-posttest scores prove the CCVLES questionnaire results. The CCVLES questionnaire which includes indicators of story dilemma feelings, teacher support, critical

thinking, and contextual chemistry, shows that 38% of students are very high for these four indicators and 62% of students are in the high category. It shows that students believe that they have good critical thinking skills and are interested in dilemma stories, the teacher also plays an active role so that students learn actively, and the students can learn chemistry in their lives(Rahmawati et al., 2021). These results are obtained through the 5E Learning cycle model with the dilemma stories approach that can change attitudes, opinions, and mindsets accompanied by students' feelings of critical thinking skills. Through this learning approach and model, teachers can evaluate learning by looking at the results of the pretest-posttest combined with the observations, CCVLES questionnaires, and student reflective journals. This invention is expected to be a scientific treasure. Learning chemistry, including the buffer concept, can be intended to improve critical thinking skills based on constructivist learning theory so students can learn from the surrounding environment.

4. CONCLUSION

The application of the dilemma stories approach with the 5E learning cycle model can improve students' critical thinking skills, which is indicated by the pretest-posttest results, where as many as 15% students are in the high improvement category, 29% are in the medium improvement category, and 12% are in the low improvement category, 12% students included decrease categorization and 32% students included stagnant categorization. The analysis of the dilemma stories' decisions, interviews, CCVLES questionnaires, and reflective journals also prove that students are invited to think more critically and apply chemistry in life through learning with the dilemma story approach. The observations show that the critical thinking skills in each learning syntax of the 5E Learning Cycle model with the story dilemma approach have been implemented well. Based on this study, future studies are expected to explore the implementation of dilemma stories approach based on transformative learning combined with another model learning and subject in school that will help students to enhance their 21st century skills.

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REFERENCES

Bilgin, I., & Coşkun, H. (2013). The Effect of 5E Learning Cycle on Mental Ability of Elementary Students. *Journal of Baltic Science Education*, *12*(5), 592–607.

De Oliveira, A. F. (2020). Buffering Function: a General Approach for Buffer Behavior. *The Journal of Engineering and Exact Sciences*, *6*(3), 0387–0396. https://doi.org/10.18540/jcecvl6iss3pp0387-0396

Demircioglu, & Ayas. (2005). Conceptual Change Achieved through A New Teaching Program on Acids and Bases. *J. Chem. Educ. Res. Pract*, *6*(1), 36–51.

Elfrida, E., Hadinugrahaningsih, T., & Rahmawati, Y. (2017). Study of Dilemmas Stories Approach on Salt Hydrolysis Material with Thinking Aloud Pair Problem Solving Method. *JRPK: Jurnal Riset Pendidikan Kimia*, *7*(2), 91–100. https://doi.org/10.21009/jrpk.072.02

Facione, P. A. (2011). Critical Thinking: What It Is and Why It Counts. *Insight Assesment*, 1–23.

Fauzi, F., & Mustadi, A. (2019). Learner Autonomy of Science Using 5E Learning Cycle. *Pedagogia : Jurnal Pendidikan*, *8*(2), 287–299. https://doi.org/10.21070/pedagogia.v8i2.2424

Fox, M. S., Greenberg, J. W., & Trookman, J. M. (2015). An Algebraic Derivation of Buffer Capacity. *World Journal of Chemical Education*, *3*(5), 124–126. https://doi.org/10.12691/wjce-3-5-4

Ghazivakili, Z., Norouzi Nia, R., Panahi, F., Karimi, M., Gholsorkhi, H., & Ahmadi, Z. (2014). The role of critical thinking skills and learning styles of university students in their academic performance. *Journal of Advances in Medical Education & Professionalism*, *2*(3), 95–102. Retrieved from

http://www.ncbi.nlm.nih.gov/pubmed/25512928%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4235550

Hake. (1999). *Analyzing Change/Gain Scores*. USA: Dept. of Physics, Indiana University.

Jerković, H. (2012). *Transformative Learning Theory*. (114), 155. https://doi.org/10.1002/ace

Kitchenham, A. (2008). The evolution of John Mezirow's transformative learning theory. *Journal of Transformative Education*, *6*(2), 104–123. https://doi.org/10.1177/1541344608322678

Kusumaningrum, I. A., Ashadi, A., & Indriyanti, N. Y. (2017). Scientific Approach and Inquiry Learning Model in the Topic of Buffer Solution: A Content Analysis. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012042

Lovat, T., Toomey, R., & Clement, N. (2010). *International Research Handbook on Values Education and Student Wellbeing*. Springer.

Maulidia, N. C., Hamid, A., & Sholahuddin, A. (2019). 5e Learning Cycle ModelAssisted Lkpd Based on Representation Level To Improve Critical Thinking Ability. *Jurnal Inovasi Pendidikan Sains*, *10*(2), 145–154.

Mezirow, J. (2012). Learning to think like an adult: Core concepts of transformation theory. In *The handbook of transformative learning: Theory, research, and practice*. Jossey-Bass.

Miles, M. B., & Huberman, M. (2005). *Qualitative Data Analysis*. Jakarta: UI Press.

Mutlu, A., & Sesen, B. A. (2016). Evaluating Of Pre-Service Science Teachers' Understanding Of General Chemistry Concepts By Using Two Tier Diagnostic Test. *Journal of Baltic Science Education*, *15*(1), 79–96.

Nurhayati, H., Rahayu, S., & Yahmin, Y. (2016). The Influence of Solubility Chemistry Learning With LC-5E with SSI Context on Critical Thinking of High School Students. *JPS (Jurnal Pendidikan Sains)*, *4*(4), 137–143. Retrieved from http://journal.um.ac.id/index.php/jps/article/view/8192

Orgill, M., & Sutherland, A. (2008). Undergraduate chemistry students' perceptions of and misconceptions about buffers and buffer problems. *Chem. Educ. Res. Pract*, *9*, 131.

Ormrod, J. E. (2008). *Educational Psychology Developing Learners*. Jakarta: Erlangga.

Rahmawati, Nurbaity, & Marheni. (2014). Engaging Students in Social Emotional Learning : the Role of Dilemma Stories in Chemistry Learning. *Proceeding of International Conference On Research, Implementation and Education of MAthematics And Sciences 2014, Yogyakarta State University*, 123–134. Yogyakarta: Implementation And Education Of Mathematics And Science Yogyakarta State University.

Rahmawati, Y., Taylor, E., Taylor, P. C., & Koul, R. (2021). Student empowerment in a constructivist values learning environment for a healthy and sustainable world. *Learning Environments Research*, *24*(3), 451–468. https://doi.org/10.1007/s10984-020-09336-9

Rosmilawati, I. (2017). Konsep Pengalaman Belajar dalam Perspektif Transformatif: Antara Mezirow dan Freire. *Prosiding Seminar Nasional Pendidikan FKIP UNTIRTA*, 317–326.

Runisah, Herman, T., and Dahlan, J. (2017). Using the 5E Learning Cycle with Metacognitive Technique to Enhance Students ' Mathematical Critical Thinking Skills. *International Journal on Emerging Mathematics Education (IJEME)*, *1*, 87–98. https://doi.org/10.12928/ijeme.v1i1.5698.

Salame, I. I., Ramirez, L., Nikolic, D., & Krauss, D. (2022). Investigating students difficulties and approaches to solving buffer related problems. *International Journal of Instruction*, *15*(1), 911–926. https://doi.org/10.29333/iji.2022.15152a

Septian, I. D., Susilaningsih, E., & Sumarti, S. S. (2020). Misconception Analysis of Buffer Material using Three Tier Multiple Choice Test assisted by CBT for SMAN 9 Semarang. *Journal of Innovative Science Education*, *9*(1), 40–49. Retrieved from http://journal.unnes.ac.id/sju/index.php/jise

Taylor, E. (2009). *Adding zest to science education: Transforming the culture ofscience classrooms through ethical dilemma pedagogy*. Saarbrucken: VDM.

Taylor R. (2007). *Re-imagining science education: Engaging students in science forAustralia's future*. Camberwell: Vic: ACER Press.

Winarti, Nahraniah, & Iriani. (2021). Validity of learning devices of buffer solution material based on dilemma stories to increase students' sustainability awareness. *Conference Series*, 1–7. https://doi.org/10.1088/1742-6596/1832/1/012028