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Fostering students' critical thinking skill in chemistry through science, technology, society, environment (STSE) collaborative learning

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Abstract: Critical thinking, need to be possessed by 21st-century individuals. This study aimed to analyze students' critical thinking skills on the Science, Technology, Society, and Environment (STSE) learning approach. Post-test non-equivalent control group design was adopted in this quasi-experiment research. Through random sampling technique, 69 students at one public senior high school in Sleman Yogyakarta, participated as a research sample, which divided into 2 classes. Students in experimental class (N=35) has been learn about electrolyte non-electrolyte topic through collaborative learning based STSE approach. While, the other students in the control class (N=34), taught by student center learning. In the fifth meetings, students' critical thinking skill was measured as a research data through an essay questions instruments that has been empirically validated. Afterwards, research data were analyzed using independent sample t-test. Moreover, the p-value shown in the analysis results was 0.009. This result indicate at the 95% confidence level there is a significant difference in students' critical thinking skill between the experimental class and the control class. The partial eta squared value shows that STSE learning approach has an effect to fostering students' critical thinking in learning chemistry, there was 9.8%.

Keywords: chemistry education, collaborative learning, STSE learning approach, critical thinking skill.

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INTRODUCTION

Global challenge requires learning activities that actually related to the current development and needs. The concept of learning in the 21st century era relates to individual competence to develop their abilities in 21st century skills in order to face future challenges. Competencies such as communication skills, critical thinking, digital literacy, problem solving and collaboration are highly recommended to be trained in learning activities in schools (Ridwan, Rahmawati & Hadinugrahaningsih, 2017). Through learning activities oriented to the needs of the 21st century, it is hoped that students will become individuals who have skills in the field of information media technology innovation, as well as life skills (Arifin, 2019). Critical thinking skills, as one of the competencies needed in the 21st century, need to be the focus initiated in learning activities. Through critical thinking skills, students will be able to mastering the concepts they learn by paying attention to the clarity of the sources of information being studied, associating and synthesizing the knowledge obtained so that they can be applied in their daily lives (Ridwan, et.al., 2017). Also, in chemistry learning that is taught in secondary education. The implementation of chemistry learning based on the 2013 curriculum aims to achieve these 21st century skills, one of which is critical thinking. Based on the results of previous research, students' critical thinking skills still need to be improved. The statement of the research results is supported empirically through an international evaluation called PISA. Based on the 2018 Programme for International Student Assessment (PISA) results, Indonesian students in the Science category are still ranked 71st out of 79 countries. The average score obtained is 396 (OECD, 2018). This result is still in the category below the international average of 500 (OECD, 2018). As research conducted by Utami (Utami, Saputro, Ashadi, et. al., 2016) shows that the critical thinking skills of students in chemistry learning are in the sufficient category. This means that efforts are still needed to make students' critical thinking better. Many efforts have been made to improve students' critical thinking skills through innovative learning strategies proposed by researchers. Student-centered learning as one of the features of the 2013 curriculum in Indonesia, it is proposed that students be able to play an active role in processing information obtained during teaching and learning activities, while teachers act as facilitators (Kaendler, Weidmann, Rummel & Spada, 2015). Therefore, as an effort to grow students' critical thinking skills, educators need to create an active learning atmosphere. Learning interventions through appropriate strategies, media, and learning activities will support the improvement of students' critical thinking (Sa'Adah, Suryaningsih & Muslim, 2020). It is an urge for educators to be able to implement learning strategy efforts so that Indonesian students have 21st century skills so they can compete globally.

As already mentioned, the learning strategy is one of the ways to innovate the implementation of learning that aims to improve students' critical thinking. The learning proposed in several studies related to students' critical thinking skills is learning that involves students in problem solving activities by applying rational and reflective thinking to reach a decision. To be able to solve problems, students need to associate various information obtained. The active participation of students in gathering information leads to interactions between students to complement the information obtained by each student (Schoor, Narciss & Kondle, 2015). This interaction is one of the characteristics of collaborative learning (Wanner & Palmer, 2018). Collaborative learning is students' learning in group that focuses on the initiative of each group member to cooperate and complement each other, even without a clear division of tasks. Each student has the same opportunity to collect information that is related to the learning topic in order to obtain a concept formation as a result (Chandra, 2015). In collaborative learning activities, students get the opportunity to fostering their critical thinking skills through identifying problems given in learning activities and developing the problem-solving strategies (Abubakar & Arsyad, 2015; Le, Janssen & Wubbels, 2017). The given problems can be analyzed in an integrated manner from a scientific and several point of view, such as environment, technology, and their daily life activity. Therefore, to support the achievement of these learning activities, a relevant learning approach is needed.

In accordance with the characteristics of collaborative learning, STSE (Science, Technology, Society, Environment) learning approach has chosen in this study because the STSE learning approach focuses on the activities of students in conducting investigations to gain knowledge of science, environment, technology, and society in a related way (Poedjiadi, 2005). This investigation activity means providing opportunities for students to develop their knowledge of solving problems that are expected to arise (Yoruk, Morgil & Secken, 2009). Learning chemistry as a collection of knowledge consisting of facts, concepts, laws, and principles confirms that chemistry includes scientific thinking which for students is considered an abstract concept. Therefore, learning chemistry is strived to be close to everyday phenomena in the natural environment around students. Each component of STSE learning which is presented in the form of articles on issues or scientific phenomena in the environment that allows students to develop thinking skills in forming beliefs about the chemistry topics being studied (Utami, Saputro & Ashadi, 2016). Previous research that has been conducted by Hairida and Lukman (2017) shows, the STSE approach can improve students' critical thinking skill during their learning activity on chemistry. Thus, this study aimed to analyze the effect of collaborative learning with the STSE approach on students' critical thinking, especially on the topic of electrolyte non-electrolyte solutions. The topic was chosen because several studies explored the difficulties of learning chemistry among students, that indicated from student cognitive test results that were still below the minimum completeness criteria.

METHOD

This study was conducted as quasi experimental research, specifically a post-test non-equivalent control group design was adopted. The research sample were drawn from 69 students at one senior high school in Yogyakarta, Indonesia, who will learn about electrolyte nonelectrolyte topic. Cluster random sampling technique was adopted. The determination of the sample was carried out based on a number of science classes in the school. Randomly, two classes were selected as the experimental class (N=35) and the control class (N=34).

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The STSE learning approach was used on the experimental class that is intended to the learning process taught to the everyday life phenomenon, which includes four elements of the STSE (Science, Technology, Society, Environment). Meanwhile, the scientific approach has been prepared for the learning activity in the control class. Learning activities are carried out during five meetings; 4 meetings for teaching and learning activities and 1 meeting for posttest. Teaching learning activities in the experimental and control class was carried out by the same teacher. Experimental class students learn about the topic through the discussion group method as one of the characteristics of collaborative learning. Each group gets a worksheet with the STSE approach that has been designed by the researcher. The worksheet covers the topic of electrolyte nonelectrolyte solutions that are part of science, which integrates towards knowledge the environment, technology and society. In addition, assignments related to the topics studied are also presented as an evaluation of learning in each meeting. The difference in learning activities between the two classes is in the core learning activities as shown in the Table 1.

Table 1. Teaching learning activity

	Experimental Class	Control Class
Preliminary activity	Before the core learning activities, the teacher divides students into 8 discussion groups in one class.	As an introduction, the teacher presents pictures of phenomena related to the topic of non-electrolyte electrolyte solutions. Through this phenomenon, students get initial questions that encourage students' thinking activities.
Core activities *)	In accordance with the stages of the STSE learning approach, learning in the experimental class consists of 5 stages. As a group, students discuss the STSE worksheet. 1. At the *invitation* stage, students analyze actual issues or problems that are real in the community life. This issue is presented by the teacher as an article on a worksheet that corresponds to the topic of non-electrolyte electrolyte solutions. 2. In the *exploration* stage, students get the opportunity to analyze issues based on scientific opinions and concepts they know. At this stage, students form their own concept of understanding through various literatures. 3. At the *solution* stage, students discuss with their friends in a group, about problem solving of the issues. Collaboratively, students can complete and strengthen the concepts that have been obtained by each member of the group. 4. At the *application* stage, students are given the opportunity to write down the ideas of the group discussions results related to the problem solving of the issues on the worksheet. 5. Concepts that have been learned through group discussions are evaluated in the form of assignment questions which are part of the *follow-up* stage in learning activities with the STSE approach.	1. As stimulation, students did an *observation* towards the phenomenon object displayed by the teacher. Through this stage, students are expected to be able to find facts about the relationship between the displayed object and the topic to be studied. 2. After the observation activity, teacher guides students to identified the scientific concept through *questioning* activities. Diagnosis questions from students will help them to find concepts they need to know and learn. 3. To determine supporting concepts, students study various references at the *collecting information* stage. This activity is a follow-up to the questioning activity. At this stage, students read more learning resources, and paying attention to the question diagnosis of the object that has been observed. 4. The concepts that students have learned, are collected and processed in the *association* stage. At this stage, information processing is carried out by finding the link between one information and another, as well as confirming the accuracy of conflicting information. 5. Students have the opportunity to *communicate* what they have learned through the retelling the relationship between the presented figure of the phenomena with the learning topics concept.
Closing activity	The teacher provides feedback and confirmation towards the concepts that was obtained by students.	The teacher provides feedback and confirmation towards concepts that students have learned.

*) Core activity step (National Science Teacher Association, 2003; Reid, 2008)

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Data collection techniques used was test. Examination technique used to measure students' understanding about the topic of electrolyte and non-electrolyte. The instrument employed in this study was a set of questions developed by researchers that consist of 8 essay items that has been empirically validated. Based on the validity-reliability analysis results, 7 of 8 questions were valid with the good category of reliability of 0.70 (Ghozali, 2011). The instruments' indicator for critical thinking skills can be seen in the Table 2. Furthermore, because researcher have two groups -experiment and control, the research data analysis technique was carried out through independent sample t-test anaylsis, the decision criteria for hypothesis testing are accepted if the significance value obtained is less than α (0.05) (Ghozali, 2011).

Table 2. Critical Thinking Instrument's Indicator

Critical Thinking Aspect [7]	Indicators	Cognitive Level						Question Number
		C1	C2	C3	C4	C5	C6	
Interpretation	Students understand the problems shown on a series of electrolyte test kits by writing down the characteristics of light flashes and bubbles formed in 3 types of solutions: $C_6H_{12}O_6$, NH_4OH, and NaOH appropriately.			√				1
Analysis	Students identify the relationship between the questions, statements, and the concept of the electrolyte properties of the vinegar and salt solutions given in the questions by making appropriate explanations.				√			2
	Students identify the relationship between the state of being weak when exposed to diarrhea through statements, and the concept of electrolyte properties by making appropriate explanations.				√			7
Evaluation	Students use the right strategy in solving the case of the relationship between the flow of electricity outside the body and the state of the body being exposed to water when viewed from the complete and correct concept of electrolytes.					√		5
	Students use the right strategy in solving the case of PLN electricity flow with the Yogyakarta flood when viewed from the complete and correct electrolyte concept					√		6
Inference	Students make conclusions from the experimental data on the electrolyte properties of the sample solution in the form of *air sumur*, sea water, river water and lake water appropriately.			√				4
	Students make procedures, experimental design, and write the conclusions using the electrical conductivity testing tools and materials provided, briefly and clearly.						√	3

RESULTS AND DISCUSSIONS

Before performing the t-test analysis, several test conditions must be met, such as: normality and homogeneity. Analysis of the prerequisite test results will be considered eligible for t-test if the Significance obtained is greater than 0.05 (Ghozali, 2011). The normality and homogeneity tests were carried out on the students' critical thinking post-test scores which were presented respectively in Table 3 and Table 4, as follows.

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Table 3. Normality Test Results of Students' Critical Thinking Data

Group	N	Mean	SD		Sig.
Control	34	62.276	9.62	0.34	Normal
Experiment	35	68.92	11.38	0.32	Normal

Table 4. Homogenity Test Results

Variable	N	Sig.	Conclusion
Critical thinking	69	0.101	Homogen

The post-test data of experimental class students and control students which were analyzed showed a significance value of normality and homogeneity greater than 0.05, meaning that the data were normally distributed and homogeneous so that they met the requirements to be continued in t-test analysis (Ghozali, 2011). The results of t-test analysis are shown in Table 5, used as a basis for discussion and decision making whether collaborative learning with the STSE approach has an influence on students' critical thinking skills on the topic of non-electrolyte electrolyte solutions.

Table 5. Independent t-test Analysis Results

Group	P	Conclusion*)	Partial Eta Squared
Experiment & Control	0.009	Significantly different	0.098

*) Confidence level of 95%

The P-value was showed in Table 5 is sufficient to indicate that at the 95% confidence level there is a significant difference in students' critical thinking skill between the experimental class and the control class. The partial eta squared value of 0.098 means that there is 9.8% of the STSE approach has an effect towards students' critical thinking skills (Richardson, 2010).

Table 6. Descriptive Analysis Results

Group	N	Mean	SD
Control	34	62.06	11.38
Experiment	35	68.80	9.62

One of the effects of the STSE can be identified through the description analysis toward posttest score that was students' critical thinking skills. The experimental class that studied with the STSE approach produced an average critical thinking score of 68.80, which is higher than the control class 62.06. However, students' score obtained was under the completion minimum criteria (*KKM*).

The results of the research analysis show that 9.8% of students' critical thinking is affected by collaborative learning based on STSE approach (Richardson, 2010). The percentage shows that the effect is not too big, meaning that there are other aspects that affect students' critical thinking skills. During the learning process, students in the experimental class gave good responses by showing their enthusiasm in teaching and learning activities. Collaborative learning with the STSE approach, provides students with experience in discussing and solving problems in their groups. Through this experience, activities in learning activities were encouraged students to understand the chemistry concept in a followed-up knowledge, starting from identifying phenomena, explaining scientifically why these phenomena occur, how these phenomena affect society, and how technology plays a role in solving these problems. The diagnosis of these questions becomes a stimulus for students to think critically (Hairida & Lukman, 2017). Moreover, the results of collaborative learning with the STSE approach in the experimental class, relatively has higher average score than the control class, as shown in Table 7.

Table 7. Average Score of Critical Thinking Aspect on Each Group

Group	Critical thinking aspect			
	Interpretation	Analysis	Evaluation	Inference
Experiment (N=35)	85	76	69	62.9
Control (N=34)	83	58	69	62

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The students' critical thinking skills in this study were divided into four aspects of critical thinking, namely interpretation, analysis, evaluation, and inference. This aspect of critical thinking skills is adapted from Facione in Normaya (Karim & Normaya, 2015). The differences in the acquisition of critical thinking scores in the experimental class and the control class are influenced by collaborative learning activities based on STSE is 9.8%, because the STSE learning stage is dominated by thinking, arguing, discussing, and evaluating the concepts they already know. These activities are relevant to support students' critical thinking (Astuti, Manurung & Juriani, 2019).

The result on the Table 7, revealed that the students' critical thinking ability of interpretation aspects in the experimental class was at an average value of 85. Interpretation skills were tested through a series of electrolyte test kits, students are required to be able to write down the characteristics of the flashes of light and bubbles formed in 3 types of solutions: $C_6H_{12}O_6$, NH_4OH, and NaOH. Most students both in the experimental class and in the control class can interpret the phenomena given as test questions. This achievement could be influenced by student activity in collaborative learning activities with the STSE approach in chemistry teaching learning class. In the collaborative activity, students guided to identify the problems on the issues presented in the invitation stage of STSE based on the scientific concepts they already have (Yoruk, Morgil & Secken, 2010). Diagnostic questions from students that obtained through the article analysis were raised as group independent instruction, so that each of students in the collabortive group were encouraged to learn the relevant chemistry topics to explain the phenomena given critically (Hairida & Lukman, 2017).

Actually, student' interpretation could not be communicated if the critical thinking of analysis aspect was not supported in the teaching intervention. Students' critical thinking ability of analysis aspects in the experimental class was at an average value of 76, meanwhile higher than control class of 58. Analytical skill were tested through identifying the relationship between the questions, statements, and the concept of the electrolyte properties of the vinegar and salt solutions given in the questions by making appropriate explanations. On the STSE exploration stage, students get the opportunity to collect references and form their own understanding related to the topic being studied (Poedjiadi, 2005). Such as in the teaching learning intervention, each student has different ideas and questions about the problem given. In this collaborative learning, each group member is open to each other about their thinking, especially regarding the function of electrolytes in the human body, which is then presented in the analytical ability test questions such as the relationship between the human body that would being weak when exposed to diarrhea through statements, and the concept of electrolyte properties by making appropriate explanations. Exactly, to state these concrete explanations, students need to analyze the relevant topic from credible source, so that they have the same opportunity to feel able to solve problems by discussing together, through controversial phenomena presented in discussion groups. Continously, they have the opportunity to access to various types of knowledge areas relevant to a given problem (Pedretti, 1999).

In one group, students can work together to participate in evaluating the concept of the subject matter obtained. There is no competitive aspect to collaborative learning (Yazichi, 2006), although there is no division of tasks among group members (Cooper, Cox, Nammouz & Case, 2008). Table 7 reveal that students' critical thinking ability of evaluation aspects in the experimental class was at an average value of 65. The closest phenomenon to student life in Jogja is during the rainy season and it causes flooding on several roads, how the flow of electricity outside the body and the state of the body being exposed. They need to use the right strategy in solving the given phenomena. When they need to evaluate about the strategy in solving the case of electricity flow with the Yogyakarta flood when viewed from the complete and correct electrolyte concept. Unfortunately, some students still did not reach the expected answer by relating the electrolytes of water to the electrolytes of the human body. Whereas, with collaborative learning activities, students learn to associate concepts that have been studied together.

Through the STSE learning, the problem-solving design that is part of the application stage in the STSE approach in student worksheets requires students to integrate their knowledge of science with knowledge of technology, the environment, and its impact on society. Furthermore, students can make solutions about the problem phenomena given which are part of the inference aspect based on scientific evidence. Unfortunately, inference aspect has the lowest score, that was 62 both at the experimental and controll class. The inference ability measured in this study was how students make a conclusion from

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the experimental data of well water, sea water, river water and lake water appropriately through the procedures, experimental design, tools and materials that they have independently design, briefly and clearly**.** This means that students have not been able to design experiments and prove the problems given independently based on the concept of knowledge they have built on the topic of non-electrolyte electrolytes. Whereas collaborative learning contributes to providing opportunities for students to experience diverse learning so that they are able to increase the potential for reasoning about the problem inference. Various joint investigative activities become their investment to be able to present the proposed investigative action (Gathong & Chamrat, 2019).

Previous research has viewed collaborative approaches as a form of unstructured cooperative learning (Cooper, Cox & Nammouz, 2008). It means that students in groups can work together without formal roles. In the heterogeneour characteristics, students work together to achieve the objectives of teaching-learning activity (Yusuf, 2014). Trough these activity, students was entails to assessing their view points on the issue that has been given (Abubakar & Arsyad, 2015). Moreover, when collaborative learning activities that facilitate students to engage in the teaching-learning process combined through STSE learning approach, activity of discussing problem or phenomenon and finding the problem solving regarding topic of electrolyte non-electrolyte solution could be fostering students' critical thinking (Hairida & Lukman, 2017) to become meaningfull learning. Learning activities become more meaningful for students because students have a dominant role during classroom learning activities with the STSE approach. Learning activities are organized to create opportunities for students to maximize their thinking skills. Conceptualizing, solving problems, making decisions, and answering various facts through STSE improves students' critical thinking skills with the paradigm of student activity domination to learn (Syahmel & Jumadi, 2020).

In spite of students' critical thinking in the control class has relatilely low average score than the experimental class, does not means that scientific approach was not appropriate to fostering students' critical thinking. Duran (2016) suggest that students' critical thinking can considered through encouraging students in the teaching learning activity. Such as in the scientific learing, when students asking questions about problem that has been possed in the aperseption stage, they should generate to think about the question. These activity has a role to fostering students' critical thinking skills. Such as on the previous research, scientific approach give an significat positive effect towards students' understanding and critical thinking skill. It is caused by students has an opportunity to discover their own concepts through scientific activity, individuaaly or in group discussions. Also, that may provides students to gain the meaningful knowledge through the critical thinking ability in interpreting problems given in the aperseption stage that involves logical reasoning and evaluating information to taking valid decision (Syarifudin, 2017). However, results of this study could has different results when STSE learning approach applied in different way.

CONCLUSIONS

This research was to analyze students' critical thinking skills during chemistry teaching learning activity conducted through collaborative learning based on the Science, Technology, Society, and Environment (STSE) learning approach. Data analysis results shows significant difference in students' critical thinking skill between the experimental class and the control class. Moreover, seeing the result of the research, collaborative learning based on STSE learning approach also reveal the effect to fostering students' critical thinking of 9.8% in electrolyte non-electrolyte topic. It was means that there were still 90.2% of other factors that affect students' critical thinking skills. As a reflection of the results of this study, chemistry learning which is presented by providing knowledge of everyday scientific phenomena can be applied in learning activities. This shows that studying chemistry is not just a matter of counting and memorizing but knowing how the direct impact of what is learned in everyday life. In addition, innovative collaborative learning strategies can be done with a type of learning approach that can be done by teachers for fostering students' critical thinking skills.

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