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The Effectiveness of Inquiry Social Complexity to Improving Critical and Creative Thinking Skills of Senior High School Students

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This research aimed to determine the effectiveness of the Inquiry Social Complexity (ISC) learning model to improve critical and creative thinking skills of senior high school students in Indonesia. The research method used was experimental with pre-test-post-test group design. The research sample were 32 students using the ISC model and 30 students using Discovery Learning in the acid-base material. The data were analysed using the ANCOVA test resulting in F = 79.381 with a significance level of 0.000 ($p < 0.05$), meaning that there were significant differences between using the ISC model and using the Discovery Learning. There was a gap of 39.66% between the pre-test and post-test results of the experimental class and 24.83% of the control class. It can be concluded that learning process using ISC learning model is very effective to improve students' critical and creative thinking skills.

Keywords: inquiry social complexity, critical and creative thinking (CCT), senior high school, learning model, thinking

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INTRODUCTION

Critical and creative thinking (CCT) skills are needed in living life in this fluctuated or changing world (Tsai, 2013). The development of the 21st century requires the existence of creative human beings who continue to work critically and creatively for the nation's progress. In fact, the critical and creative thinking has a significant contribution to building a sustainable future (Mitchell & Walinga, 2017; Baharin, Kamarudin, & Manaf, 2018). CCT Skills are high-order thinking skills needed in the 21st century (Ataizi & Donmez, 2014; Nilsson & Gro, 2015). These skills are related to logical, rational and reflective thinking skills and the mental process of analyzing or evaluating information systematically to decide exactly what actions to take and to believe in. One has different ways of thinking and ideas in making something new and different from others. This can be achieved by getting along with an environment that is used to thinking creatively. Chemistry learning is dominantly oriented to cognitive skills (Facione, 2013; Tsai, 2013; Dyankova, 2018).

According to (Trilling & Fadel, 2009) the 21st-century curriculum contains four elements of competencies (critical thinking, creative thinking, collaboration, and communication skills), which can help students in facing the challenges of the 21st-century globalization era. It is essential to provide 21st-century skills learning for students (Scherer & Gustafsson, 2015; Chalkiadaki, 2018). It is based on the Partnership for 21st Century Skills that critical and creative thinking (CCT) skills are very important and need to be empowered for students to develop critical and creative thinking (CCT) skills (Kan'an, 2018; Menggo et al., 2019).

In fact, during learning, teachers have not been able to explore the empowerment of the students' CCT skills to the fullest. They use PowerPoint more and learning with discussion still dominates. Assignments and exercises given do not lead optimally in empowering students' CCT skills. They have not implemented the five inquiry lesson syntaxes in the chemistry learning process. They already know the scientific approach including observing, asking, analyzing, gathering information, and communicating, but they have not been implemented optimally in the learning process. The students have not all been actively involved in learning, which means that socially they have not fully got along in solving problems that occur during learning. Thus, communication needs to be emphasized effectively to accommodate students in active and effective learning.

The learning model and method used by the teachers also do not involve High-Order Thinking Skills (HOTs). This is evidenced in the learning and assessment instruments which are still focused on cognitive achievement (Azizah, Sahil, & Hashim, 2011; Elbastawissy & Kadry, 2014; Sasai, 2017; Stanković, Maksimović, & Osmanović, 2018). 21st-century learning in Indonesia is carried out in the 2013 curriculum learning which has a specific purpose that students have the skills needed for social life in the present and future. The 2013 curriculum learning, among others, is carried out by using innovative learning models and methods to train and integrate 4C (Creativity and Innovation, Critical Thinking and Problem Solving, Communication, Collaboration), literacy, HOTs, and Character Education Strengthening (Kemendikbud, 2013).

Chemistry learning is expected to facilitate and accommodate students' CCT skills in senior high schools.

Students are expected to have CCT skills. CCT skills were improved by designing the integration of the inquiry lesson learning model which consists of five skill syntaxes, namely (1) observation, (2) manipulation, (3) generalization, (4) verification, (5) application; with Social Complexity which consists of five skill syntaxes namely (1) teaming and collaboration, (2) interpersonal skills, (3) personal responsibility, (4) social responsibility, (4) interactive communication; which to become learning model, namely Inquiry Social Complexity (ISC). ISC learning model has five skill syntax elements, namely (1) observation team, (2) reconstruction, (3) socialization, (4) verification, and (5) applied communication. ISC learning model can accommodate students to interact based on effective communication indicators to gain broader knowledge and CCT skills.

Students' CCT skills can be empowered by developing and implementing the learning model that has the characteristics of supporting the development of CCT skills. ISC learning model is a model that emphasizes discovery, investigation, constructivism, thinking skills, and knowledge integration. Thus, one's communicative and cognitive skills in interacting with others, in the context of learning, will increasingly shape their communicative skills, which are specific aspects of social relations between individuals and knowledge developed together with others, to be more meaningful. ISC through learning syntax is expected to facilitate and accommodate to empower students' CCT skills. Based on the background above, it is necessary to conduct a research entitled investigating the effectiveness of the Social Complexity Inquiry (ISC) learning model to improve critical and creative thinking (CCT) of senior high school students in Indonesia.

The Study Hypotheses

The hypothesis used in this study is:

$H_0 : \mu_1 \leq \mu_2$ (Average Critical and Creative Thinking using the ISC model is no better than the DL model)

$H_1 : \mu_1 > \mu_2$ (The average Critical and Creative Thinking using the ISC model is better than the DL model).

METHOD

Study Sample

The research method used was experimental with pre-test-post-test group design. The research population was tenth-grade science students of all Islamic senior high schools of Surakarta City (Indonesia) in 2018/2019 academic year. The sampling technique used was cluster random sampling. The research subjects were 62 students consisting of 32 students as the experimental class using the ISC model and 30 students as the control class using Discovery Learning (DL) model in the acid-base material. Both classes got a pre-test before receiving treatment and doing the post-test.

Instrument

The instrument for measuring indicators of CCT skills, according to some experts, is based on this conceptual construct for CCT skills into six aspects, namely, (1) Problem Sensitivity, (2) Analysis, (3) Inferences, (4) Making Elaboration, (5) Evaluation, and (6) Novelty (PAIMEN). The instrument test for measuring critical and creative thinking skills was the assessment rubric with a range of scores 1-4, as many as eleven items. The instrument has been validated by using the moment product person correlation test provided that if r > r table then, the item is valid. If r < r table, then the question is invalid. The lowest score of the instrument validity test is 0.138 and the highest 0.787 > f table with 33 student respondents with the value of r = 0.344 (value of r product-moment). This means that the instrument about critical and creative thinking skills is valid. The reliability score obtained by Cronbach's Alpha is 0.793 > 0.344, which means that each item is reliable to implement.

Data Analysis

To find out the effectiveness of the module after the learning process, normalized gain scores (<g>) of the pre-test and post-test of the experimental class and the exiting class were used. A module is a learning package that contains a unit of learning material, which can be read or studied by someone independently. The module is a teaching unit that is arranged in a particular form for learning purposes.

$$\langle g \rangle = \frac{S_{post} - S_{pre}}{100\% - S_{pre}}$$

Note:

<g> = gain factor

S pre = pre-test mean score (%)

S post = post-test mean score (%)

The normalized gain score calculation was interpreted using the gain level criteria between the pre-test and post-test scores in the experimental class as shown in Table 1.

Table 1
Interpretation of Index Score Criteria of Gain Score

N-Gain	Interpretation
0,7 < g < 1	High
0,3 ≤ g ≤ 0,7	Medium
0 < g < 0.3	Low

Source: (Hake, 1999).

FINDINGS

Comparison of the Results of the Pretest and Posttest in Terms of CCT Aspects

The following are the results of the pre-test and post-test scores of the CCT aspects as the experimental class using the ISC model and 30 students as the control class using Discovery Learning (DL) model in the acid-base material. The results of the data analysis of the percentage of comparison of the scores obtained in the pre-test and post-test per an aspect of CCT between the experimental class and the control class are presented in Table 2.

Table 2
The Results of the Data Analysis of the Percentage of Comparison of the Scores in the Pre-test and Post-test Per an Aspect of CCT

Aspects School-Based Curriculum	Experimental Class		Control Class	
	Pre-test	Post-test	Pre-test	Post-test
Problem sensitivity	51%	85,5%	49%	73%
Analysis	46%	90%	45,5%	70%
Inferences	44,5%	90%	45,5%	72,5%
Making elaboration	52%	82%	46%	66,5%
Evaluation	47%	86%	44%	70%
Novelty	43%	88%	45%	72%
Mean	47,25%	86,91%	45,83%	70,66%

Table 2 shows that the score percentage per aspect of CCT in the experimental class, which includes the aspect of problem sensitivity, is 85.5%, the analysis aspect is 90%, the inference aspect is 90%, the make elaboration aspect is 82%, the evaluation aspect is 86%, and novelty aspects at 88%. The pre-test means the score is 47.25%, and the post-test mean score is 86.91%.

Based on the results of the experimental class pretest and posttest, there was a gap of 39.66%. The results of the descriptive analysis of the students' CCT scores are shown in Table 3 as follows.

Table 3
The Results of the Descriptive Analysis of the Students' CCT Scores

Test Types	Class	Number	Min Score	Max Score	Mean	SD
Pre-test	Experimental	32	34.09	56.82	47.80	6.07
	Control	30	38.64	59.09	48.94	5.56
Post-test	Experimental	32	63.64	100.00	87.00	7.51
	Control	30	52.27	84.09	70.83	7.53

Table 3 shows that the lowest pretest means a score of the control class is 38.64 and the highest is 59.09 with the mean of 48.94 and standard deviation of 5.56. The lowest posttest means of the control class is 52.27 and the highest is 84.09 with the mean of 70.83 and standard deviation of 7.53. The lowest pretest means of the experimental class is 34.09 and the highest is 56.82 with the mean of 47.80 and standard deviation of 6.07. The lowest posttest means a score of the experimental class is 63.64 and the highest is 100 with the mean of 87.00 and standard deviation of 7.51.

The Normalized Gain Score

The pretest and posttest scores were calculated to determine the effectiveness of improving CCT skills. The N-gain calculation results were interpreted using the gain level criteria (Hake, 1999). The results of the mean gain scores of the experimental class and the control class are shown in Table 4.

Table 4
N-gain Score of Experimental and Control Classes

Class	Mean Gain Score	Category
Experimental	0.75	High
Existing	0.42	Moderate

Table 4 shows that the N-gain score of the experimental class is 0.75 with high criteria compared to the control class of 0.42 with moderate criteria. It can be concluded that there are differences in CCT skills between the control class and the experimental class. However, the difference in the control class is smaller than the experimental class with moderate criteria. Meanwhile, the difference in the experimental class is greater with high criteria. It can be concluded that the ISC model can be implemented to improve students' CCT skills.

ANCOVA Test Analysis on Students' CCT Skills

The results of the ANCOVA test analysis on students' CCT skills. Analysis of Covariance (ANCOVA) was conducted to determine the significant differences in improving students' CCT skills. Prerequisite tests were in the form of normality using the Kolmogorov-Smirnov test and homogeneity test using the Levene test. Before the ANCOVA test, the N-gain scores of students' CCT skills are usually distributed and homogeneous. The results of the normality and homogeneity tests can be seen in Table 5 and Table 6.

Table 5
Normality Test Result

	Class	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
N-gain (<g>)	Control	.118	30	.200
	Experimental	.138	32	.126

Table 6
Homogeneity-Test Results

	Levene Statistic	df1	df2	Sig.
N-gain (<g>)	1,093	1	60	.300

Table 5 and 6 show that based on the normality test, the data were normally distributed and based on the homogeneity test, the data were homogeneous. The next step was to conduct the ANCOVA test. The results of the ANCOVA test can be seen in Table 7.

Table 7
The results of ANCOVA Test of N-gain Scores of the Students' CCT Scores

Dependent Variable: Gain					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,707[a]	1	1,707	79,381	.000
Intercept	21,440	1	21,440	996,941	.000
Classes	1,707	1	1,707	79,381	.000
Errors	1,290	60	.022		
Total	24,852	62			
Corrected Total	2,997	61			

a. R Squared = .023 (Adjusted R Squared = .012)

Based on the results of the covariance analysis, the significance level obtained is 0.000. This significance score is less than 0.05 ($p < 0.005$), so H_0 is rejected and the research hypothesis is accepted, which shows that there is a very significant difference in the effect of the ISC learning model to improve students' CCT Skills

Effect-Size Test Analysis Result

The test results of the effect-size test using the Cohen, Hedges's g, and Glass's test with Rstat Effect Size Calculator on the N-gain score are shown in Table 8 below.

Table 8
The Result of Analysis of Effect-Size Test

Class	Mean	SD	Cohen	Hedges's	Glass	Interpretation
Experimental	0.754	0,131	0.867	0.899	0.760	Large
Control	0,422	0,161				

The results of the effect-size test analysis show that the use of the model in learning has a great effect on empowering CCT skills as indicated by the results of the effect-size test based on the formula of Cohen d of 0.867, Hedges's of 0.899, and Glass's of 0.760.

DISCUSSION

The Inquiry Social Complexity (ISC) model implemented on the topic of chemical material has the potential to improve students' CCT skills as indicated by the results of the ANCOVA and effect-size tests. The ANCOVA test results show the effect of using the ISC learning model to improve students' CCT skills with the results of covariance analysis with $F = 79.381$ and the significance of 0.000. For the effect-size test, results were in large criteria. The level of effectiveness of ISC in improving CCT skills from the effect-size test analysis with the Rstat Effect-Size Calculator on N-gain scores shows that the use of models in learning has a great effect on empowering CCT skills as indicated by results of the effect size test based on the formula of Cohen d of 0.876, Hedges's of 0.899, and Glass's of 0.760. The results of this effect size are the effects of the treatment given to the variables to be developed (Sullivan & Feinn, 2012).

The results of the syntactic activity of the ISC learning model are based on several studies of learning theory that train students' high-order thinking skills. This ISC learning model trains the aspects of students' CCT through six syntaxes covering 6 aspects, namely, problem sensitivity, analysis, inferences, making elaboration, evaluation, and novelty (PAIMEN). The results of this research are relevant to the research conducted by Wenning, (2011), Kim, (2006), Vygotsky, (1978) stating that ISC learning model can improve students' CCT skills.ISC learning model is effective to improve the exploration of every aspect of CCT skills of senior high school students in the learning process.

The observation team syntax of the ISC learning model on chemical material is that students work together in teams to observe phenomena that raise problems to be examined and studied in learning. This syntax is effective in training the sensitivity aspect of students' CCT skills, namely the ability to detect and produce a unique idea of a question or situation they face. Fluency is the indicator of producing unique ideas from the questions they face. Flexibility is predicting the view of a problem from various perspectives.

The reconstruction syntax in the ISC learning model on the chemical material is that students in each team make ideas and collect data both qualitatively and quantitatively. This syntax is effective in training the aspects of students CCT skills on analysis aspect, namely the ability to identify the truth between questions and concepts and make decisions with the right information. Interpretation is the indicator of identifying evidence-based on existing data. The reasoning is connecting reasons that support or oppose decisions made based on facts.

The socialization syntax in the ISC learning model on the chemical material is that students in small groups express ideas with others on the data collected. Each of them has an important role to participate effectively in the group. This syntax is effective in training the inferences aspect of the students' CCT skills, namely the ability to explain the truth of the data and the prevailing theories and defend their opinions to be accepted by others. Clarity is the indicator that describes the meaning of the term used. In-sight is the sharpness of understanding to be communicated to others.

The verification syntax of the ISC learning model on the chemical material is that students in the team do the test and analyze the truth of facts they find by relating it to the underlying theory they have known from the previous stages. This syntax is effective in training the aspects of students CCT skills. Making elaboration is the ability to describe things in more detail to be understood by others. Generating is the indicator of developing something to be better understood by the student himself or others. Redefinition is reviewing an issue based on a different or the same perspective as others to be understood.

The applied communication syntax of the ISC learning model on the chemical material is that students in the group express their opinions orally and in writing alternately to agree on the truth with which the teacher's direction is correct in learning and can be applied in daily life. This syntax is effective in training the evaluation aspect of the students CCT skills, namely the ability to assess the credibility of a question or presentation by describing one's perceptions, experiences, situations, decisions, beliefs and evaluating the logical strength of actual inferential relationships or other forms of representation. Self-regulation is thinking process awareness in understanding the capabilities owned. An overview is reexamining thoroughly the decisions taken.

The effectiveness of the ISC model on the chemical material to improve each aspect of students' CCT skills is also supported by the teacher’s role in observing and students’ activities during the learning process. The observation process in the implementation of the ISC model syntaxes is running optimally. This shows that the ISC model has been proven to be more effective in improving the aspects of students’ CCT skills. However, the empowerment of the students’ high-order thinking skills, namely CCT skills, also involves many other factors such as the characters of psychology, intelligence, and the learning environment (Budsankom et al., 2015). In empowering the exploration of these students’ skills, teachers also play an important role in developing and implementing the right pedagogy in the development process and taking appropriate steps so that CCT skills can be optimally empowered (Uerz et al., 2018; Margot & Kettler, 2019). In addition, teachers are also required to have skills in managing the class well and facilitating the students to actively participate in the learning process so that they are not only recipients of information but also information users and managers (Kusaeri & Aditomo, 2019).

The ISC model encourages students to be active and to communicate effectively in learning activities. Students will experience meaningful learning because they learn from direct experiences independently (Amineh & Asl, 2015; Bergman & Beehner, 2015; Matei & Antonie, 2015; Perdana, Budiyono, Sajidan & Sukarmin 2019). The ISC model stimulates students' curiosity, develops their knowledge and understanding and reasoning of scientific ideas and communication. Students are more actively involved in learning activities intellectually and emotionally. They can maximize their logic (Tsai, 2013; Orgad & Spiller, 2014; Zubaidah et al., 2017; Ryzal, 2018). Their cognitive skills improve significantly, and they are better at delivering their opinions to others. The ISC model can develop their cognitive processes, self-confidence, and evaluation skills in examining things and solving problems (Peters et al., 2016; Taut & Rakoczy, 2016; Rachmatullah & Ha, 2019; Maksimović & Osmanović, 2019). Students are motivated, inspired, and encouraged to have high expectations of the material they learn (Scherer & Gustafsson, 2015; Hasan & Abdelrazek, 2016). The model can also increase their sharpness and imagination to think critically, creatively and selectively. One can choose ideas that are more creative, more original, and more useful for him/herself or the surrounding environment. Students can have high order thinking skills, especially CCT skills (Facione, 2013).

CCT skills are high-order thinking skills that make students able to explore themselves to think neutrally, objectively and logically (Yee et al, 2016; Siew & Mapeala, 2016). They need to be trained in CCT skills to be able to develop their intellectual skills, argumentation skills, cognitive knowledge, conceptual understanding, and problem-solving (Biasi, Vincenzo, & Patrizi, 2018; Demiral & Çepni, 2018; Zhdanko, 2019). Therefore good CCT skills are beneficial for students in the short term at school and long term in the work world in the their future lives (Ahrari et al, 2016; Sulaiman et al., 2017) CCT skills will also greatly help students in facing various challenges in the 21st century, especially in the globalization era that is full of innovation, so that they can compete with many innovations that emerge (Chalkiadaki, 2018; Yanti, 2018).

CONCLUSIONS

Based on the analysis results, the implementation of Social Complexity (ISC) learning model can improve the critical and creative thinking skills of senior high school students in Indonesia. The effectiveness of the ISC learning model can be seen from from the significance of CCT skills. The statistical analysis test, the ANCOVA test results, resulted in the F = 79,381 with a significance level of 0.000 ($p < 0.05$), meaning that there re significant differences between the experimental class and the control class. The result of the calculation of n-gain scores indicate that students' CCT skills in the experimental class is 0.75 with high category compared to the control class of 0.42 with moderate category. The increase in the gain score occurs in every aspect of the indicators with moderate criteria. Therefore, the ISC learning model is very effective for improving students' CCT skills in the aspects of problem sensitivity, analysis, inferences, making elaboration, evaluation and novelty.

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