IMPACT OF EXPLICIT SCIENTIFIC INQUIRY INSTRUCTION HYBRID MODE WITH SOCIOSCIENTIFIC ISSUE CONTEXT ON STUDENTS' CRITICAL THINKING SKILLS IN CHEMICAL KINETICS

Eli Khusmawardani[1], Muntholib[*2], Yahmin[3]

[1, 2, 3] Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang

**Corresponding author: muntholib.fmipa@um.ac.id*

Abstract. *This study aims to explore whether Explicit Scientific Inquiry Instruction (ESII) Hybrid Mode in the context of Socioscientific Issues could improve the students' critical thinking skills. The research design was a one group pretest-posttest design. The research sample was 31 science eleventh graders at SMA Mojosari for the academic year 2021/2022. The data was collected using a critical thinking skills test on Chemical Kinetics which consists of 27 valid questions with a Cronbach Alpha reliability of 0.756. A paired-samples t-test showed that the Explicit Scientific Inquiry Instruction (ESII) Hybrid Mode in the Socioscientific Issues context improved students' critical thinking skills ($p = 0.00 < 0.05$). The improvement was strong as its N-gain score was 0.58 (upper–medium category) and d-effect size was 1.40 (much larger than typical category). This shows that statistically ESII hybrid mode in the context of SSI can improve students' critical thinking skills. Therefore, this strategy can improve students' critical thinking skills in the instruction that allows students to interpret, analyze, explain, evaluate, and draw conclusions.*

Keywords: *esii; ssi; hybrid learning; critical thinking, chemical kinetics*

INTRODUCTION

The rapid development of information and communication technology has an impact on the pattern of people's lives, including policies in education. Educational reform emphasizes the development of transferable skills by students in facing the challenges of the 21st Century so as to produce graduates who are skilled and able to respond to changes in a fast and complex world. In an effort to anticipate world changes, Indonesia prepares itself by growing and developing the competencies or skills needed in the 21st Century, including analytical skills such as critical thinking [1]. The 2013 curriculum emphasizes students' thinking skills and acts effectively and creatively in the abstract and concrete realm as a development from observing, asking, trying, processing, presenting, reasoning, and creating independently according to their talents and interests [2]

Critical thinking is represented as the main goal in long-term learning and is a skill that is much needed in the world of work [3] and the social environment in which adequate decision-making is needed [4]. Critical thinking is defined as the ability to analyze and evaluate everyday life problems in order to make logical decisions or arguments. The critical thinking skills of Indonesian students, especially in science learning, have not been fully achieved and are categorized as low based on the results of several survey studies [5]-[9]. This is very concerning, so it is necessary to develop students' critical thinking skills to improve the quality of education.

Scientific inquiry is a learning approach that emphasizes the process of discovery like a scientist looking for the truth by involving students' learning experiences so that students' skills can be trained. Scientific inquiry learning provides opportunities for students to gain an understanding of the scientific method to develop critical thinking skills, self-regulation, and understanding of certain topics [10]. *Explicit Scientific Inquiry Instructional* (ESII) is a scientific inquiry learning that has just been developed and has become a learning trend in

the context of content which is expected to be able to improve the optimal quality of learning [11]. ESII practice students to conduct guided scientific inquiry from understanding scientific questions, designing investigations, collecting and analyzing data, and interpreting and explaining scientific evidence [12]. Scientific inquiry activities of students such as experiments in laboratories and the discovery process have a positive effect on critical thinking skills because inquiry activities lead students to acquire concepts independently through information processing, oral and written communication, and critical thinking [13]. ESII consists of six stages of learning such as orientation, conceptualization, investigation, argument construction, validation, and enrichment [11]. The orientation phase prepares students to carry out a scientific investigation by presenting the SSI context and prior knowledge. The conceptualization phase provides students with problem statements or scientific questions related to the concepts to be studied which can trigger investigation activities. In the investigation phase, students conduct scientific inquiries, collect evidence, collect and process data, draw conclusions, and interpret results. in the argument construct phase, students make a short report and explain the findings of the investigation, in the validation phase students discuss the level of validity of their findings through large group discussions. In the enrichment phase, students deepen and expand their scientific knowledge according to the scope of the curriculum using the relevant SSI context.

Innovative learning requires contexts that are relevant in everyday life to direct students to be involved in the learning process in understanding, reflecting, and creating meaningful knowledge [14] so that there is no gap between the abstract concepts students have and the reality in everyday life. The context of socio-scientific issues is a means to contextualize learning and learning approaches that are useful for motivating chemistry learning and contributing to the development of student skills. Socioscientific issues context as the right approach is presented in learning which brings students to be involved in discussions or debates [15] which has a positive effect on critical thinking skills. The involvement of SSI creates individuals who are able to make decisions from complex problems, both factual and conceptual. In other words, the SSI context trains students to analyze problems, evaluate sources to be used, and create solutions because of the interaction between the three components; educators, students, and the context of the problem to be solved [16].

The Covid-19 pandemic has shifted face-to-face learning to online learning to prevent the very fast transmission of the virus and the increasing number of cases in Indonesia. WHO data as of 27 June 2021, Indonesia ranks 17th as the 20 countries with the highest increase in cases, especially East Java Province which is one of the 5 provinces that experienced the highest increase in cases. The increase in Covid-19 cases has resulted in the learning process running less than optimally, so it needs to be combined with learning modes that are in accordance with the conditions and needs in the field. Distance learning is considered less effective considering the large number of learning materials. Hybrid learning by utilizing technology is used as an alternative learning during the Covid-19 pandemic. Hybrid learning provides an avenue for academic achievement in science education [17] and provides a more engaging and interactive learning environment [18] by combining face-to-face learning and online learning that requires an internet network carried out synchronously or asynchronous.

The subject matter of chemical kinetics includes phenomena that can be observed, analyzed, and concluded such as the effect of concentration on reaction rates [19][20]. This topic also covers concepts that can be used to explain phenomena such as collision and activation energy theories. In addition, the concepts of reaction rate are widely applied in everyday life so that it can be appointed as a context for studying chemistry related to controversial social issues in order to attract the attention of students. Therefore, this subject matter is interesting to be adopted as research material involving inquiry, socioscientific issues, and critical thinking skills. The study objective is to explore whether ESII Hybrid Mode using Socioscientific Issues can impact students' critical thinking.

METHOD

This study uses a quasi-experiment one group pretest-posttest research design [21] as shown in Figure 1.

Pre-test	*Treatment*	*Post test*
O_1	$\rightarrow$ X $\rightarrow$	O_2

Figure 1. One Group Pretes-Posttest Design

Notes:

O_1: The initial test is a written test to determine the initial critical thinking ability of the chemical kinetics

X: ESII learning using SSI context mode hybrid

O_2: The final test is a written test for critical thinking skills at the end of the chemical kinetics

The population of the study was eleventh graders students of science at SMA Negeri 1 Mojosari in 2021/2022. The sampling technique is cluster random sampling. The instrument used is a multiple-choice critical thinking test with Facione's indicators [22]: validated analysis, interpretation, inference, evaluation, and explanation.

Data analysis of critical thinking ability used a pair t-test, N-gain score, and Cohens effect size. A pair t-test was conducted to determine whether there were differences in understanding skills before and after treatment. The t-test was carried out if the normality and homogeneity tests of the sample were fulfilled, meaning that the data were homogeneous and normally distributed. The normality test used the Kolmogorov-Smirnov test and the homogeneity test used the Levene test using SPSS for Windows 23.0 Dependent Sample t-T-test test program using SPSS 23.0 for Windows at 95% confidence level (α= 0.05). Determination of the N-Gain score aims to determine the effectiveness of learning based on the description of the increase in learning outcomes scores before and after treatment using SPSS 23.0 for Windows. The results of N-gain are then interpreted using the criteria [23] in Table 1.

Table 1 N-Gain Score Criteria

N-Gain Score (g)	Criteria
< 0.3	Low
0.3 < *g* < 0.7	Medium
> 0.7	High

Cohen's test effect size to determine the effectiveness of the treatment by knowing the effect of treatment on the variables measured. The criteria for the magnitude of the effect [24] can be seen in Table 2.

Table 2 N-Gain Score Criteria

Effect size score (*d*)	Criteria
d < 0.20	Low
0.20 < d < 0.50	Medium
0.50 < d < 0.80	Larger
d > 0.80	Much larger

RESULT AND DISCUSSION

Critical thinking skills data were obtained from the results of the pretest and posttest using a validated multiple-choice critical thinking test instrument. The pretest was conducted before ESII using SSI context mode hybrid learning while the posttest was conducted after ESII using SSI context mode hybrid learning. In this study, learning combines face-to-face meetings where educators and students conduct direct learning while online learning is carried out asynchronously. In face-to-face learning, students listen to the explanation of the main concepts by the teacher and conduct experiments directly, while in asynchronous learning students listen to video explanations of material and simple experimental videos and then make a summary of the material. Argument validation in asynchronous learning is done through online discussion.

The critical thinking test instrument uses critical thinking aspects developed by [22] including: analysis, interpretation, inference, explanation, and evaluation. The results of the normality tests are in Table 3.

Table 3 Normality Test Results

Value Data	Sig.
Pre-test	0.065
Posttes	0.127

Based on Table 3, it is found that the significance value of the pretest and posttest data is greater than the significance level of 0.050 which indicates that the data is normally distributed. The results of the homogeneity tests are in Table 4.

Table 4 Homogeneity Test Results

Value Data	Sig.
Pretes	0.879
Postes	1.000

Based on Table 4, the data significance value is greater than the significance level of 0.05 which indicates that the data is homogeneous. The research data is said to meet the assumption that it is homogeneous and normally distributed so that the research hypothesis test can be carried out using the paired sample t-test. The paired sample t-test was conducted to determine the differences in students' critical thinking before and after treatment. The results of hypothesis testing can be seen in Table 5.

Table 5 Hypothesis Test Results

Paired sample t-test	Sig.
	0.000

Based on table 5, the significance value is smaller than 0.05 which indicates that there is a significant difference in students' critical thinking skills before and after learning ESII using SSI context mode hybrid. This is supported by the average post-test results of critical thinking before treatment (X = 27.94) and after treatment (X = 69.87).

The effectiveness of ESII using SSI context mode hybrid is known from the calculation of N-gain score and Cohens effect size. The results of N-gain score and effect size Cohen's tests are in Table 6.

Table 6 N-Gain Score and Effect Size Results

Value Data	Score	Category
N-Gain	0.5806	Medium
Effect Size	1.400	Much Larger

Based on table 6 shows that ESII using SSI context learning mode hybrid effectively improve students' thinking skills.

The effectiveness of ESII using SSI context mode hybrid on students' critical thinking skills, one of which is influenced by the syntax of ESII using the SSI context, which gives students experience in conducting scientific inquiry in acquiring scientific knowledge so that they can construct each aspect of Facione's critical thinking skills.

The orientation stage is carried out by presenting several SSI contexts such as decaying apples, coral reefs, drying salt, tenderizing meat with papaya leaves, social-distancing during the Covid-19 pandemic, alcohol in health and volcanic eruptions. The orientation stage stimulates curiosity to solve problems related to the presented SSI context so that it requires students to carry out scientific investigations. The existence of SSI helps students improve critical thinking skills, especially in the inference aspect by looking for evidence based on existing issues and connecting them to obtain a solution in the form of a scientific argument (make a conclusion) or a decision. Learning science by involving social issues allows students to use scientific knowledge meaningfully to be applied to decision making in the real world rather than just learning science facts [25].

Evidence and arguments are important components of solving problems. However, the two components cannot be separated from the concepts (scientific knowledge) that students must understand first at the conceptualization stage as a basis for strengthening the argument with existing evidence. The conceptualization stage plays an important role in the inquiry process where students are provided with mature concepts to make an argument or decision that can be accounted for after conducting an investigation. If students have sufficient knowledge (mature concepts) they will find it easier to explain properly [26].

The investigative stage can improve critical thinking skills because students carry out investigations based on problem statements that have been made at the orientation stage. Students conduct an investigation by collecting some data according to the concepts obtained at the conceptualization stage. The data that has been collected will be processed first (students

perform data analysis and data interpretation) so that they get a conclusion from the appropriate evidence (make an inference) from the problem statement. The conclusions obtained are in the form of arguments so that students are able to make scientific explanations based on evidence/facts and appropriate concepts.

Conclusions in the form of arguments that have been obtained must be validated first in order to obtain the truth of a fact with a more valid concept through a validation process involving experts, namely educators (teachers). In the expert validation process, students make presentations on the arguments that have been obtained and other students provide an assessment of both suggestions and comments if there is a discrepancy between the arguments between groups. At this stage students are trained to evaluate several arguments which must be accompanied by valid evidence and data so that credible conclusions can be obtained. The three stages of ESII using SSI context mode hybrid include: investigation, argument formation, and expert validation which are the core of the critical thinking formation process because they train critical thinking skills so that at this stage students must play an active role in each process. Students' critical thinking skills can be improved through a knowledge discovery process that involves students in searching, collecting, analyzing, synthesizing, and evaluating information to create ideas, and solve problems through student collaboration [27].

The deepening and enrichment stage, practice students to strengthen critical thinking skills and deepen their knowledge by presenting the SSI context with questions containing critical thinking indicators such as: analysis, interpretation, inference, evaluation, explanation. Questions that use critical thinking indicators can practice students' critical thinking.

The hybrid mode of ESII using SSI context is the development of an inquiry learning model that involves students' activities to conduct scientific inquiry so that students are more active in the learning process. Learning is fully controlled by students while educators act as motivators, facilitators and directors. Educators only present the SSI context, encourage students to provide opinions about the SSI context, provide solutions if there are obstacles in the learning process, and direct students' thinking processes to achieve the expected goals [28]. Discovery-based practice learning students to construct the concept of chemical kinetics critically and independently. ESII using SSI context has the characteristics of a learning model that can improve critical thinking skills, such as emphasizing a scientific approach (scientific inquiry) by applying discussion, presentation, and experimental methods [29]. Learning that involves student inquiry has an effect on increasing higher-order thinking skills such as critical thinking [26,30] in interpreting, analyzing, and explaining skills [31]. Likewise, if implemented in the context of SSI, it can improve critical thinking skills [13].

CONCLUSION AND SUGGESTION

The hybrid mode of ESII using SSI context indeed improved students' critical thiking skills in chemical kinetics. Students' critical thiking skills was improved with a very large effect size and upper-medium N-gain. Their critical thinking skills were significantly improved from an under-competent level before to a mastery level after the instruction of chemical kinetics. This paper shows that inquiry-based blended instruction in the context of socioscientific issues can improve students' critical thinking skills. We can use this learning strategy to improve the critical thinking skills of students who cannot attend school every day.

REFERENCES

[1] Suardana, I. N., Redhana, I. W., Sudiatmika, A. A. I. A. R., & Selamat, I. N. 2018. Students' critical thinking skills in chemistry learning using local culture-based 7E learning cycle model. *International Journal of Instruction*, *11*(2), 399–412. https://doi.org/10.12973/iji.2018.11227a

[2] Permendikbud. 2016. *Standar Kompetensi Lulusan Pendidikan Dasar dan Menengah*.

[3] Danczak, S. M., Thompson, C. D., & Overton, T. L. 2017. "What does the term Critical Thinking mean to you?" A qualitative analysis of chemistry undergraduate, teaching staff and employers' views of critical thinking.

Chemistry Education Research and Practice, *18*(3), 420–434. https://doi.org/10.1039/c6rp00249h

[4] Dwyer, C. P., & Walsh, A. 2020. An exploratory quantitative case study of critical thinking development through adult distance learning. *Educational Technology Research and Development*, *68*(1), 17–35. https://doi.org/10.1007/s11423-019-09659-2

[5] Fernanda, A., Haryani, S., Tri Prasetya, A., & Hilmi, M. 2019. Analisis Kemampuan Berpikir Kritis Siswa Kelas XI pada Materi Larutan Penyangga dengan Model Pembelajaran Predict Observe Explain. In *Jurnal Inovasi Pendidikan Kimia* (Vol. 13, Issue 1).

[6] Khoirunnisa, F., & Widhia Sabekti, A. 2020. Profil Keterampilan Berpikir Kritis Siswa pada Materi Ikatan Kimia. *Jurnal Pendidikan Kimia Indonesia*, *4*, 26–31. https://ejournal.undiksha.ac.id/index.php/JPK/index

[7] Maghfiroh, R. K. 2020. *Keterampilan Berpikir Kritis Siswa SMA Negeri di Kabupaten Situbondo pada Materi Reaksi Redoks dan Elektrokimia*. Universitas Negeri Malang.

[8] Manik, A., Suryaningsih, S., Muslim, B., Studi, P., Kimia, P., Tarbiyah, I., & Keguruan, D. 2020. Analisis Berpikir Kritis Kimia dalam Menyelesaikan Soal Two-Tier Berdasarkan Level Kemampuan Mahasiswa. *Jambura Journal of Educational Chemistry*, *2*(1).

[9] Rohiat, S., Amir, H., & Yunita, S. 2018. *Analisis Kemampuan Berpikir Kritis Mata Pelajaran Kimia pada Siswa Kelas XI IPA SMAN 1 Kepahiang*. *2*, 33–38.

[10] Seranica, C., Purwoko, A. A., & Hakim, A. 2018. Influence of Guided Inquiry Learning Model to Critical Thinking Skills. *Journal of Research & Method in Education*, *8*(1), 28–31. https://doi.org/10.9790/7388-0801022831

[11] Muntholib, M., Hidayati, K., Purnajanti, L., Utomo, Y., & Hariyanto, H. 2021. Impact of explicit scientific inquiry instruction on students' scientific argumentation skills in salt hydrolysis. *AIP Conference Proceedings*, *2330*. https://doi.org/10.1063/5.0043237

[12] Muntholib, Khusmawardani, E., Utomo, Y., Muchson, & Yahmin. 2020. Development and implementation of multiple-choice chemical literacy survey in acid-base chemistry. *AIP Conference Proceedings*, *2215*. https://doi.org/10.1063/5.0000547

[13] Mahanani, Rahayu, & Fajaroh, F. 2019. Pengaruh Pembelajaran Inkuiri Berkonteks Socioscientific Issues terhadap Keterampilan Berpikir Kritis dan Scientific Explanation. *Jurnal Kependidikan*, *3*(1), 53–68.

[14] Subiantoro, A. 2018. *Pembelajaran Biologi berbasis Socio-scientific Issues (SSI) untuk Mengasah Keterampilan Berpikir Tingkat Tinggi*. https://www.researchgate.net/publication/323218921

[15] Rahayu, S. 2019. Socio-scientific Issues (SSI) in Chemistry Education: Enhancing Both Students' Chemical Literacy & Transferable Skills. *Journal of Physics: Conference Series*, *1227*(1). https://doi.org/10.1088/1742-6596/1227/1/012008

[16] Imaduddin, M., & Khafidin, Z. 2018. Pembelajaran Berbasis Socio-Scientific Issues di Abad ke-21. *Journal of Natural Science Teaching*, *01*(02), 102–120. http://journal.stainkudus.ac.id/index.php/Thabiea

[17] Kazu, İ. Y., Kurtoğlu, C., Ii, Y., İbrahim, I, Kazu, Y., & Prof, A. 2022. Investigation of the Effectiveness of Hybrid Learning on Academic Achievement: A Meta-Analysis Study. *Cemre Kurtoğlu Yalçın, English Teacher, Ministry of National Education International Journal of Progressive Education*, *18*, 2022. https://doi.org/10.29329/ijpe.2022.426.14

[18] Astuti, T. N., Sugiyarto, K. H., & Ikhsan, J. 2020. Effect of 3D visualization on students' critical thinking skills and scientific attitude in chemistry. *International Journal of Instruction*, *13*(1), 151–164. https://doi.org/10.29333/iji.2020.13110a

[19] Chang, Raymond. 2010. *Chemistry*. McGraw-Hill.

[20] Murry, J., & Fay, R. 2012. *Chemistry* (A. Jaworski, Ed.; Sixth). Pearson Prentice Hall.

[21] Sugiyono. 2017. *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D.* Alfabeta.

[22] Facione, P. A. 2020. *Permission to Reprint for Non-Commercial Uses Critical Thinking: What It Is and Why It Counts*. Insight Assessment.

[23] Hake, R. R. 1999. *Analyzing Change/Gain Scores*. http://lists.asu.edu/cgi-bin/wa?A2=ind9903&L=aera-d&P=R6855

[24] Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences Second Edition*.

[25] Foulk, J. A., Friedrichsen, P. J., & Sadler, T. D. 2020. *Teaching with a timeline activity*. The Science Teacher. www.nsta.org/highschool

[26] Utami, B., Saputro, S., Ashadi, A., Masykuri, M., Probosari, R. M., & Sutanto, A. 2018. Students' critical thinking skills profile: constructing best strategy in teaching chemistry. *IJPTE : International Journal of Pedagogy and Teacher Education*, *2*, 63. https://doi.org/10.20961/ijpte.v2i0.19768

[27] Wale, B. D., & Bishaw, K. S. 2020. Effects of using inquiry-based learning on EFL students' critical thinking skills. *Asian-Pacific Journal of Second and Foreign Language Education*, *5*(1). https://doi.org/10.1186/s40862-020-00090-2

[28] Qamariyah, S. N., Rahayu, S., Fajaroh, F., & Alsulami, N. M. 2021. The Effect of Implementation of Inquiry-based Learning with Socio-scientific Issues on Students' Higher-Order Thinking Skills. *Journal of Science Learning*, *4*(3), 210–218. https://doi.org/10.17509/jsl.v4i3.30863

[29] Rusmansyah, Yuanita, L., Ibrahim, M., Isnawati, & Prahani, B. K. 2019. Innovative chemistry learning model: Improving the critical thinking skill and self-efficacy of pre-service chemistry teachers. *Journal of Technology and Science Education*, *9*(1), 59–76. https://doi.org/10.3926/jotse.555

[30] Sutiani, A., Silalahi, A., & Situmorang, M. 2017. The Development of Innovative Learning Material with Problem Based Approach to Improve Students Competence in the Teaching of Physical Chemistry. *Advances in Social Science, Education and Humanities Research*. https://doi.org/10.2991/aisteel-17.2017.81

[31] Farah, N., & Ayoubi, Z. 2020. Enhancing the Critical Thinking Skills of Grade 8 Chemistry Students Using an Inquiry and Reflection Teaching Method. *Journal of Education in Science, Environment and Health*. https://doi.org/10.21891/jeseh.656872