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by Slamet Suyanto

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Implementation of Socio-Scientific Issues Based Instruction to Improve Critical Thinking Skills in Biology Learning

Yakun Paristri[1,a)] and Slamet Suyanto[2,b)]

[1]Graduate Programe of Biology Education, Yogyakarta State University
[2]Departement of Biology Education, Yogyakarta State University

Corresponding author: [a)]yakunparistri@yahoo.com
[b)]slamet_suyanto@uny.ac.id

Abstract. The Socio-Scientific Issues Based Instruction is a learning model that requires students to engage in dialog, discussion, and debate. The steps of this model consists of problem analysis, clarification of science, refocus on socio-scientific dilemma, role play task, and meta-reflective activity, are appropriate steps to develop critical critical skills. Critical thinking skills consist of reasoning ability to identify problems, analyze, evaluate, interpretation, explaining and organizing ideas, defending opinions, making conclusions, evaluating arguments and making decisions with different perspectives. The aims of this paper are (1) knowing the methods that mostly used by the researchers incorporating with SSI on Biology learning, (2) knowing the grade of samples that mostly used by researchers, (3) knowing the kinds of socio-scientific issues that used by researchers, and (4) knowing the impact of SSI based Instruction on students' critical thinking skills in Biology learning. Based on a meta-analysis, it can be concluded that (1) the most widely used method is quasi experiment, (2) the most widely used sample is at junior high school level, (3) the issues that used on the researchs are controversial local and global issues that have many perspectives, and have an impact on students' moral and ethical values, and (4) SSI based instruction can be used to improve students' critical thinking skills on all education level. That are significant different average score between SSI clasroom and non-SSI classroom. Incorporating with SSI, students may develop abilities in identifiying problem, analyzing, evaluating, making conclusion, and making desicion, and, consequently, critical thinking skills would be improved.

INTRODUCTION

Learning science is an active process. It means, learning science is something student to do, not something that is done to them. Today, science teaching is informed to make desicion, analyze, synthesize, and evaluate information into classroom. It also deals with moral reasoning and ethical issues, try to understand the connections among socioscientific issues. Thus, sosioscientific issues based instruction is needed.

As a learning model, SSI based instruction has spesific character. Acording to Tal and Kedmi, the issues used in this learning activityhave characteristics as follows:

- Has to do with the biology curriculum standard
- Supported by current data
- Has the real issue
- Must be contemporary issues relevant to the subject
- Be controversial
- Has natural character and scientific process
- Need to discuss moral and ethical. [14]

The issues must be controversial and supported by current data in real life. It indicates that SSI can be found around students and their environment. In a global context, SSI can be found such as genetic engineering issues (gene therapy, cloning or stem cells) and environmental issues such as global warming and climate change. SSI can also be sourced from local communities, such as the issue of dreads in the Dieng community, Central Java, or the impact of the eruption of Mount Merapi [1].

The controversial nature of SSI and its relevance to society generate interest among students. SSI can help students to understand aspects of science that contribute to decisions about important local, societal, and global issues to gain experiences negotiating the complex issues [3].It can happen because the emergent framework of SSI (graphically presented in Fig. 1) is made up by four primary aspects: *design elements*, *learner experiences*, *classroom environment*, and *teacher attributes*. *Design elements* refer to important considerations for the designof successful SSI-based education. *Learner experiences* represent the kinds of opportunities that learners ought to have access to during SSI-based education. *Classroom environment* refers to contextual features of the learning environmentsthat are necessary for successful design and enactment of experiences. Similarly, *teacher attributes* reference characteristics and practices that teachers should assume for successful implementation of SSI-based education. *Design elements*and *learner experiences* are situated centrally in the graphic representation to show these as core features of SSI education. *Classroom environment* and *teacher attributes* are positioned more peripherally to indicate the role both of these elements play in shaping implementation of *design elements* and *learner experiences*. [23]

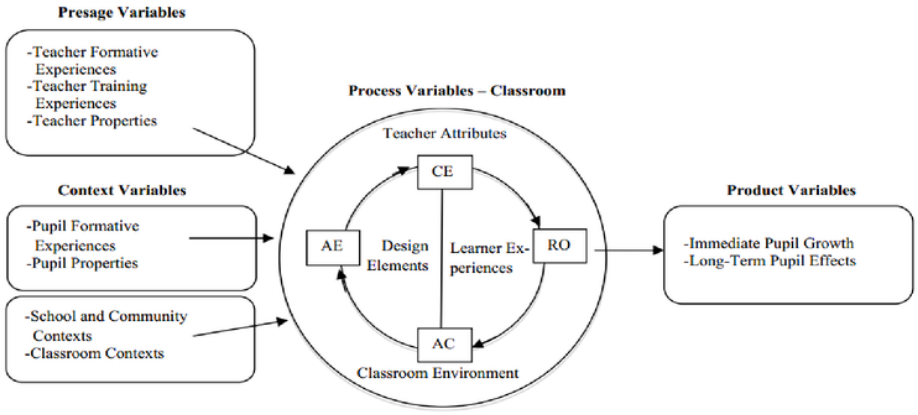

FIGURE 1. Conceptual Model of SSI-based Instruction (Adapted from Shoulders and Myers, 2013)

Experiential learning combines the aspects of concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) [6]. SSI-based instruction improves student learning experiences by allowing students to practice using scientific principles and concepts in situations similar to those they will experience in the future as citizens in a scientific society [23].In line with the emergent framework of SSI, Eilks offered five steps for instruction below:

1. Problem analysis. In this step, students are presented with an issue of interest through media reports or other strategies that highlight the reality and relevance of the issue.
2. Clarification of the science. Teachers help students understand the basic science underlying the issue.
3. Refocus on the socio-scientific dilemma. Students refocus their attention on the issue and the associated social problems or controversies.
4. Role-playing task. Students assume roles for engaging in the negotiation of SSI. These roles may include parties to the issue debate or creators of media related to the issue.
5. Meta-reflective activity. Students are encouraged to reflect on their overall experiences with the issue and the underlying science. [23]

Eilks' model offered a relatively simple model for operationalizing what it means to teach with SSI.Providing students with the opportunity to discuss or debate controversial SSI in role play step, gives them the chance to develop skills associated to critical thinking skills [9].

The urgency of critical thinking to support critical thinking education are: First, they consider the process is rationality idealism. The education significance can be analyzed equally means it is good thought so that it is a normative. Second, critical thinking is to organize students being mature in self-direction. Third, critical thinking is rational culture of education activity [19].

Critical thinking is frequenly conceptualized as one goals of science education. By broad definition it is a form of reflective thinking that ultimately helps one to decide what to believe or do. It related to many functions including evaluating the arguments of other, evaluating one's own argument, resolving conflict and understanding resolution [9]. Critical thinking skill can be indicated based on the Bloom' taxonomy, that delineates six catagories of learning: basic knowledge, secondary comprehension, application, analysis, synthesis and evaluation. The first two catagories, basic knowledge and secondary comprehension, do not require critical thinking skills, but the last four – application,analysis, synthesis and evaluation - all require the higher order thinking skills that characterizes critical throught [7].

Acording to Ennis, critical thinking skills include: (1) defines the term and consider using the definition of the appropriate criteria; (2) ask and answer questions that require an explanation; (3) focused questions; (4) to interact with others; (5) induction; (6) observe and consider the results of observation; (7) show or make assumptions; and (8) to deduce and assess the results of deduction [10]. These skills can be enhanced through the integration of socioscientific issues in the life science because the application of scientific knowledge is one of the primary concerns of the subject matter [2].The implementation of SSI in science education can push the students to be involved in a dialog, discussion, and debate actively that can provide challenges to the students to evaluate their knowledge and give a chance to rebuild their concept mastery related to the concept that they learned from their own experiences and social phenomena [20].

Based on the information above, the main questions are:

1. what kinds of methods did the research use?
2. in what grade did the research do?
3. what kinds of SSI do the researchers address?
4. did the research improve students' critical thinking skills?

METHODS

The methods used meta-analytical technique. It reviews of the journals, that study abaout socio-scientific issues, critical thinking skills, and the impact of socio-scientific issues in teaching and learning to students' critical thinking skills. Data collected base on result of the research that have been previosly undertaken. The number of Journals based on the research focus used is presented in table 1 below:

TABLE1. Research Focus of the Journals

Focus	Count of journals	Persentage
SSI in Biology Classroom	8	32 %
Critical Thinking Skills	6	24 %
SSI and Critical Thinking Skills	11	44 %

RESULTS AND DISCUSSION

The Methods And Samples Used In The Reviewed Journals

The methods and samples used in the reviewed journal are shown in figure 2 below:

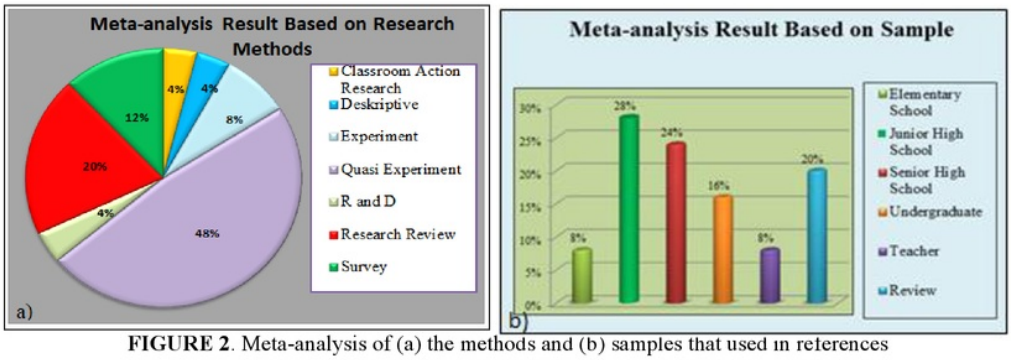

FIGURE 2. Meta-analysis of (a) the methods and (b) samples that used in references

Based on meta-analysis result of 25 studies, 48% of researchers used quasi experiment with control class and experiment class. Critical thinking skills are measured before and after treatment or compared between the control class and the experimental class. Other methods are research review (20%), survey (12%), experiment (8%), deskriptive (4%), R and D (4%), and classroom action research (4%).

The samples used by the reseachers are very diverse, from students of Elementary School up to Undergraduate. In fact, there are 8% of researchers used teachers as research samples. Most reseachers used students of Junior High School as samples (28%). Others researchs conducted on students of Senior High School (24%), students of Elementary School (8), and 20% researchers used no samples because they do a research review.

Meta-analysis Results based on Topic of SSI that Used by Reseachers

The projects of journals reviewed discussed wide variety of SSI. Topics include issues related to using science and technology to enhance human performance. Some projects focused on scientific controversies with important social implications, several studies featured learner exploration of local and/or global environmental issues. The issues that used in the researchs were controversial local and global issues that have many perspectives, and have an impact on students' moral and ethical values. Thus, the issues allow the students to solve problems from different points of view. Issues that are used in the projects are related to the topic follows:

1. Ecosystem: the erruption of Merapi mountaian and water quality
2. Bioethical: Biotechnology, environmental degradation, cancer research
3. The impact of the use of calcium carbite in ripering fruit
4. Dillemaof cigarette industry in Indonesia
5. Controversy in transgenik plants, cloning and cigarette
6. Global warming : the effect of greenhouse gases
7. Genetically modified mosquitoes
8. Genetically Modified Organisme Food controversy
9. Additivies in food
10. Waste management: management of silver company's waste
11. Biodiversity
12. Basic concept of Biology and history of life
13. ADHD (Attention Deficit Hyperactivity Disorder)

These issues are used to develop high order thinking skills during the learning process, especially critical thinking skills.

The Impact of SSI on Students' Critical Thinking Skills

Students that incorporating with SSI, have significantly improved critical thinking skills. The results of observation made during eight lesson conduct by Wilsa, Susilowati and Rahayu [21] show in table 2 below:

TABLE 2. Observation Results of Critical Thinking Skills

Observation Results	Lesson to....								Average
	1	2	3	4	5	6	7	8	
Experiment class	46.1	52.6	57.8	62.9	66.5	70.0	72.6	73.9	62.8
Control class	42.1	50.8	53.8	59.0	61.8	62.8	64.3	65.4	57.5

There are different average score between experiment and control class. The average score of the experiment class is 5.3 point higher than the control class. Based on the data from eksperiment conducted by Masfuah and Pratiwi [13]; Dewi, Suryadarma, Wilujeng and Wahyuningsih [5]; Pratiwi, Rahayu and Fajaroh[10]; Sawono, Pratiwi, Susanto and Susilo[12], average score of critical thinking test on experiment group and control group for all education level shown on table 3 below:

TABEL 3. Average Score of Critical Thinking Test on Experiment Group and Control Group

Sample	Experiment Group	Control Group	Difference
Elementary School (Grade 3td)	85,44	81,36	4,08
Junior High School (grade 8th)	79,51	75,81	3,70

Senior high School (grade 10th)	73.96	66.04	5,99
University Undergraduates	86,79	47,17	39,60

The results of the experiments showed that classroom which employed the SSI context in learning had higher average grade than the classroom without SSI context, for all education level. Research conducted by Sawono, Pratiwi, Susanto and Susilo[12] showed that the difference score between experiment group and control group of the university undergraduate is 39.60. This is the highest difference score than the other, beside the defference score of Junior high School is the lowest. This resulf is due to several factors, including the ability of teachers in presenting lessons with SSI, lesson plan used and case selection as socio-science issues. In terms of learning tools, Widhy, Nurohman and Wibowo [18] have developed learning kit that incorporating an SSI-based integrated science learning model to develop thinking skills, with the results as shown in table 4 below:

TABLE 4. Score For Learning Kit

No.	Learning Kit	Average Score		Average	Catagory
		Given By Experts	Given By Teachers		
1	Silaby	3.7	3.6	3.65	Very good
2	Lesson plan	3.5	3.5	3.50	Very good
3	Students' Work Sheet	3.5	3.6	3.55	Very good
4	Modul	3.6	3.7	3.65	Very good

Although the learning kit catagory is very good, it is important to highlight that teachers' ability is the key of classroom activity. In an SSI-based classroom, teachers must adopt a realistic view of science in order to create a connection between the ideas of sciene and the stduents' actual experiences. This can be done if the teacher presents the lesson in varied ways that encourage critical thinking and deeper discussions. In Gutierez's study, the teaching methods used were augmented by the teacher's questioning skills. In this study, teachers' questions facilitated students' learning. Questions mediated the interactive processes in the learning environment in a number of important ways especially when these served as cues and clues for students to critically think. The use of relevant and authentic socio-scientific issues encouraged and allowed students to actively evaluate both the advantages and disadvantages of science in their lives [2]. Through this method, the students were able to respond in a positive, more elaborate, wider range of explanation, and in-depth manner indicating improved critical thinking and decision-making skills. Thus, teachers play a crucial role in developing this cognitive skill among their students. Their reflections about previous classroom interactions determine their plans and expectations of what they wish to happen next [8].

The challenge in SSI depends on the ability of teachers to select and expose biological based cases or issues in the community. The issue that used in SSI is controversial in nature, has many perspectives and has an impact on students' moral and ethical values.Tidemand, Sofie, Nielsen and Alexis [4] suggest the criteria for selecting and thematising socioscientific issues: the issue should be (1) authentic, (2) relevant, (3) contentious (i.e. undetermined), (4) allow for open discussion, and (5) deal with a problem based on science and technology. Domenech and Marquez noticedthat SSI appear almost daily in the mass media. Nowadays, the media (newspapers, magazines, television, radio and the Internet), taken as a whole, are considered "the most easily accessible sources of scientific information to the general public"[9].

Subiantoro and Fatkurohman [22] used issues from newsletter to teachs about climate exchange. Cases were described as stories which were rich of problems, knowledge, and skills that were used to encourage students to think, so that they could help students think to solve the problems.In this learning application, the controversial issues arise as the characteristic of SSI induce the students to discusse and debatemore actively to train their critical thinking skills [10]. Thus, by designing researches and discussing about them, students may develop abilities in analyzing and evaluating data, and, consequently, critical thinking skills would be promoted.

On the other hands,when students have worked with SSI, they are led to emphasize personal experiences or value. Students' interpretation and evaluation of contradictory were influenced by their personal opinions and scientific knowledge. They can draw different kinds of knowledge and ideas in what they learned through socioscientific issues-based instruction, and finally, their critical thinking skills will grow. There were differences of score between the pretest and post test which show increaces critical thinking skills. Other experiments show the same result for different levels of education. Tabel 5 below shows the comparison between pre-test and post-test score for elementary school level [15]; junior high school level [5], and university undergraduate level [12].

TABEL 5. Meta-analysis Result of Comparison Between Pre-Test And Post-Test In Experiment Classroom

Sample	Pre-test	Post-test	Increased Score	Persentage (%)
Elementary School	6,33	13,04	6,71	106,00
Junior High School	54,83	79,51	24,68	45,01
Undergraduate	49,87	86,79	36,92	74,03

The increased score in elementary school is higher than the other.The research was conducted by Nuangchalerm and Kwuanthong that use 20-item analytical thinking test. This phenomenon can be explained that learning activities allow students to have thinking process based on critical examination relevant to evidence-based science [15]. The teaching method employed by the teacher was augmented by the teacher's questioning skills where questions were mostly focused on analysis, synthesis, and evaluation. Moreover, students' achievement and level of engagement depend on the types of questions teachers asked. It is therefore important that teaching and learning be set to a social activity where teachers and students construct and synthesize knowledge mutually through active processing, thinking about, and using information productively. Aside from higher-order questioning during lecture-discussions, the teacher also asked the students to do group analyses of socio scientific issues in which teacher initiated questions and gave them the opportunity to do collaborative thinking.

Dynamic process in science classroom is the result of interactions between individuals and the environment, therefore the cognitive aspect will grow [15]. Incorporating SSI in science learning creates opportunity for the students to analyze from other points of view, emphasizes critical reasoning over memorizing, promotes the practice of participatory decision making, allows students to critically evaluate, argue, discuss and debate competing scientific claims, and promotes character and moral sensitivity of students to ethical issues.

According to reference [25], the use of SSI as a context for learning can train students' critical thinking skills through three important aspects: (1) the students need to understand and describe the problem situations involving SSI; (2) the students formulate a number of problem solving solutions that enable on the situation that has learned; and (3) students need to re-evaluate the decisions they have made before the decision is communicated within the forum.

The use of SSI strategies challenge students to reevaluate their prior understandings, providing an opportunity for them to restructure their conceptual understanding of subject matter through personal experiences and social discourse [24].

Specifically, some studies measure critical thinking skills on a variety of indicators. The following table summarizes the results of the studis with sample of elementary [13], junior [19], [22] and college [11] students. Not all researchsused in this paper provide pre-test and post-test measurements. Some studies use post-test only control group designmethod, so the result of measurement for each critical thinking skill indicator is based on the acquisition of post-test value as stated in table 6 below.

TABLE6. Meta-analysis Result of Average Post-test Score in Each Indicator

Indicator	Sample	Post-test Result
make decisions or actions	Elementary School	85
	Junior High School	22,39
	Undergraduate	69,64% of sample on high criteria
Identify problems	Elementary School	92
	Junior High School	18,5% of sample on level 4 (high)
	Undergraduate	39,29% of sample on high criteia
Analyze	Elementary School	85
	Junior High School	11,1% of sample on level 4 (high)
	Undergraduate	26,79% of sample on high criteria
Evaluate	Elementary School	83
	Junior High School	3 (grade on score 60-79)
	Undergraduate	16,07% of sample on high criteria
Interpretation	Elementary School	85

	Junior High School	4 (grade on score 80-89)
Argumentation Skill	Elementary School	85
Make conclusion	Elementary School	81
	Junior High School	18,5% of sample on level 4 (high)

Based on the data, there are different result of critical thinking skill in each education level. College student have the highest point on disicion-making skills; junior student have the highest point on interpretation (average score of the sample on grade 4), and elementary students have the highest score on problem identifiying skills (average score is 92). Decision-making skill is the ability to conclude and take action from various alternative actions that exist based on various considerations. The decision is the best option, supported by data and arguments.

The argumentative skills that students use in expressing their opinions or decisions about the sociocultural issues they face are closely related to the process of acquiring knowledge or understanding of students that involves critical thinking skills. SSI provides opportunities for contextual learning situations to develop argumentative skills, moral reasoning, and informal reasoning [1]. The research conducted by Chun-YenTsai [16] use online argumentation on SSI. Students built their own arguments and evaluated arguments of others. In this process, students could search for and analyze related data online to address conflicting situations. In the other words, critical thinking is a well-directed and clear process used in solving problems, making decisions, analyzing assumptions and evaluating.

In line with Chun-Yen Tsai, Herlanti [17] found that argumentation skills can be developed by SSI based education. The attainment of students argumentation is at level two, that is, participants are able to express the claim which is accompanied by a logical reason but not yet based on strong empirical evidence. Some teachers mentioned that the role of socioscientific issues is to prepare students to make informed decisions in real life settings, outside school [4].The components of critical thinking skills that must be taught to students include the ability to (1) identify problems, (2) analyze, (3) evaluate, (4) interpretation, (5) argumentation, (6) concluting, and make decisions or actions.

CONCLUSION

Socio-scientific Issues based instruction require students to engage in dialog, discussion and debate. Based on a meta-analysis result, it can be concluded that (1) the most widely used method is quasi experiment, (2) the most widely used sample is at junior high school level, (3) the issues that used on the researchs are controversial local and global issues that have many perspectives, and have an impact on students' moral and ethical values, and (4) SSI based instruction can be used to improve students' critical thinking skills on elementary school, junior high school, senior high school and undergraduate. That are significant different average score between SSI clasroom and non-SSI classroom. Incorporating with SSI, students may increase abilities in identifiying problem, analyzing, evaluating, making conclusion, and desicion–making skill, and, consequently, critical thinking skills would improve. This is indicated by increasing post test score in SSI classroom. Based on the data, it is concluded that socio-scientific issues based instruction can improve critical thinking skills in Biology learning.

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Implementation of Socio-Scientific Issues Based Instruction to Improve Critical Thinking Skills in Biology Learning

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Instructor

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CRITERION 1

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CRITERION 2

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CRITERION 4

Criterion 4 description. Description text is optional

SCALE 1 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 2 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 3 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 4 TITLE	Text describing what meets this scale for this criterion. This text is optional.

SCALE 5 TITLE	Text describing what meets this scale for this criterion. This text is optional.

CRITERION 5

Criterion 5 description. Description text is optional

SCALE 1 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 2 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 3 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 4 TITLE	Text describing what meets this scale for this criterion. This text is optional.
SCALE 5 TITLE	Text describing what meets this scale for this criterion. This text is optional.