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Structuring a New Socioscientific Issues (SSI) Based Instruction Model: Impacts on Pre-service Science Teachers' (PSTs) Critical Thinking Skills and Dispositions

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Structuring a New Socioscientific Issues (SSI) Based Instruction Model: Impacts on Pre-service Science Teachers' (PSTs) Critical Thinking Skills and Dispositions

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Abstract

The purpose of the study was to propose a new socioscientific issues based instruction model and to investigate the impacts of new model on PSTs' critical thinking skills and dispositions in climate change unit. Quasi-experimental method was applied. The sample of the study was determined by convenient sampling and it was comprised of 90 junior PSTs. The experimental group in which SSI based instruction was implemented, consists of 45 pre-service teachers, and there were 45 pre-service teachers in the control group. Data was gathered quantitatively with the help of Turkish version of the Ennis-Weir Critical Thinking Essay Test (E-WCTET) and the California Critical Thinking Disposition Inventory (CCTDI). Analysis of covariance (ANCOVA) was used to determine the impacts of new model on the critical thinking skills and dispositions of PSTs in experiment and control groups. Findings of the study revealed that there is no statistically significant difference between the treatment and the control group's critical thinking skills scores. However, the posttest scores of the treatment group were increased. Also, results indicated that there is a statistically significant difference between the treatment and the control group's critical thinking dispositions scores. Implications for teaching practice are discussed.

Introduction

In which ways scientific issues should be learned and what aspects should be taught is a big concern for science educators, politicians, and citizens in 21st century of modern society since many scientific issues such as nuclear power plants, genetically modified organisms, organ transplantation, etc. integrate with social dimensions in this age. Those are also uncontrolled and unexpected by even advanced science and technology (e.g., avian influenza, and Zicca virus) (Kim, Ko, & Lee, 2019). Researchers coined a new term to address those: socioscientific issues (SSI) (Zeidler & Nichols, 2009). SSI are complex controversial scientific matters that are embedded in the cultural, political, economic, and ethical sides of our lives influencing our communities at the personal, regional, or global levels (Lee, Kyunghee, Kim, Jungsook, Krajcik, Herman, & Zeidler, 2013; Seckin Kapucu, 2018; Zeidler, 2014). SSI often involve science, technology, and socially related ill-structured issues such as modified organisms, climate change, shortages of food and energy, decreased biodiversity, and sustainable development. SSI frequently include open-ended problems and alternative solutions which lead people to compete with each other and they considerably live conflicts of interest embedded in these problems (Sadler, Foulk, & Freidrichsen, 2007). Herman (2015; 2018) stated that only well-informed people who think over not only their own arguments but also different interests of society can overcome these problems. Hence, integrating SSI into science instruction in schools enables students with the opportunity to construct reasonable knowledge about complicated issues (Levinson, 2006).

Incorporating SSI with science classroom inherently provides students to engage in fruitful discussions about matters of modern science (Sadler et al., 2007). Many educators widely stated that SSI is regarded as a thoughtful tool to participate in societal discussions and it promotes being a democratic citizenship of the world (Kolsto, 2001; Oulton, Dillon, & Grace, 2004; Ratcliffe & Grace, 2003; Sadler et al., 2007). Many organizations also admitted that embedding SSI in science curricula is important to educate future citizens who are experiencing lots of controversial issues in their daily lives (Australian Curriculum, Assessment and Reporting Authority, 2015; 21st Century Science Project Team, 2003; Ministry of National Education, 2018). However, while engaging in SSI has profound outcomes, individuals encounter an arising problem related to the amount of valid and invalid information available about SSI. In today's speedy communication world, SSI related information spreads through multiple media channels more often than ever before. This requires learners to extract the reliable information in a systematic way from huge body of data sources in order to make well-informed decision making as a citizen of democratic society (Hilton & Canciello, 2018; Sadler & Zeidler, 2005b; Visintainer & Linn, 2015; Walters, Green, Goldsby, & Parker, 2018). At this point, improving critical thinking (CT) is regarded as a main element of decision making in an information rich society (National Research Council, 2007; OECD, 2001). Norris, Phillips, Smith, Gilbert, Stange, Baker, and Weber (2008) asserted that the significant of improving students' critical thinking skills in order to analyze and critique arguments concerning the controversy of social applications of science and technology, because those only reflect one special group's interest which led students to make misinformed decisions. Moreover, CT guides students to make good judgments and decisions (Ennis, 1989, 1996a; Lipman, 2003).

In this context, SSI based instruction as a science education method is a useful way to help students improve skills which provide them to analyze, evaluate, and inference huge amount of SSI related information in media. Previous studies have demonstrated that SSI present prejudice-free classroom environment in which students develops CT skills (Berland, & McNeill, 2010; Gresch, Hasselhorn, & Bögeholz, 2013; Day & Bryce, 2013; Simonneaux & Simonneaux, 2009; Zeidler, Sadler, Simmons, & Howes, 2005). Nevertheless, prior studies revealed that some problematic issues arised about embedding SSI into school science class in order to improve students CT by the teacher (Lindahl & Folkesson, 2016; Evagorou & Osborne, 2013). As highlighted by Aikenhead (2006), teachers have many problems while implementing SSI in their science classrooms. For instance, they experience lack of content knowledge, structured teaching strategies, and poor resources regarding SSI. Ekborg, Ottander, Silfver, and Simon (2013) also put forth that teachers feel uncomfortable in dealing with ill-structured SSI in their science classroom, so they need extra support and guidance to cope with SSI.

Theoretical Framework

Critical Thinking (CT)

Yacoubian (2015) claimed that future citizens will come across SSI increasingly, so they need to be supported with many practices on SSI based discussions to engage in critically. They would need to generate rationale, reflective decisions, and judgments on what to believe or do. At this point, this study asserts that CT is a useful framework for addressing SSI decision making because CT consists of a certain set of skills and dispositions in order to produce reasonable decisions (Ennis, 1996; Paul, 2004). Yacoubian and Khishfe (2018) also emphasized that CT could be a fruitful framework for addressing SSI for two reasons. The former, CT is main element of decision making. The latter, huge body of CT literature enables meaningful sources to support students while they explore SSI. The CT skills are 'analyses', 'evaluation', and "inference" (Scriven & Paul, 2007; Yore, 2012). Analyzing refers to the skill of determining to discriminate real assumptions, reasons, arguments, concepts, opinions, beliefs experiences and judgments from intended ones. Moreover, this skill provides individuals to gather information from charts, graphs, diagrams, observation techniques, interviews, and statistical inferences in order to compare and contrast ideas and claims. Evaluating addresses the skill of assessing the credibility of information sources, as a person's statements, judgments, claims, ideas, and perceptions. Besides, it enables us to evaluate the reasonable strength of these resources. That is, it determines the degrees of credibility as well. Inference refers to the skill of determining core components for coming significant conclusion to construct meaningful hypothesis; to obtain reasonable results from definitions, identifications, principles, claims, evidences, and other forms of information. It permits us questioning evidence that should be supported by previous information that is plausible with promoted theories or issues (Horvath & Forte, 2011).

The CT dispositions have six sub-dimensions: 'truth-seeking', 'open-mindedness', 'analyticity', 'systematicity', 'confidence in reasoning', 'inquisitiveness', and 'maturity of judgment'(Faccione, 1990; Ennis, 1996; Horvath & Forte, 2011). Truth-seeking is a tendency of constant research for the best explanation of any claim. Open-mindedness is a tolerance and respect disposition towards other's beliefs, ideas, and values even if it is opposite to one's own. Analyticity is to anticipate the good and the bad consequences of situations, choices, proposals, and plans that may happen afterwards. Systematicity is a tendency of researching a related issue in an organized, disciplined, and cautious way. Confidence in reasoning refers to the trust in one's own reflective thinking or judgment procedure while solving problems and making decisions. Inquisitiveness is defined as a desire of knowing or intellectual curiosity. People with maturity of judgment disposition have an ability to realize the complexity of the issue encountered. As a result, the set of skills and dispositions could be beneficial resources while future citizens of democratic society engage in SSI activities in order to make good decisions and judgments.

SSI

Educators have indicated that SSI could be a foundation pillar for being used as main contexts for learning science (Sadler & Dawson, 2012). SSI includes controversial topics that are significant for community and is a multifaceted construct that citizens may require to consider as much as scientific evidence to make reasonable decisions. For instance, they should be aware of investigating social, economic, religious, ethical, and political aspects of it because decision making process demands consideration of multiple perspectives (Sadler et al., 2007).

SSI combines social dilemmas and science with conceptual, procedural, and technological oriented issues. The concept of 'socioscientific' reveals a specific engagement in social, moral, political, and science and technological depended issues (Sadler & Zeidler, 2004). SSI is the integration of controversial socially relevant issues with science. These issues focus on students' values, ethics and attitudes (Sadler & Zeidler, 2005). SSI includes open-ended inquiries that contain constructing thoughts and making decisions with social and personal standpoint perspectives (Ratcliffe & Grace, 2003). SSI is multi-answered real world problems, which have aspects of cultural, economic, and political sides that include moral and ethical controversies (Chowning, 2009). SSI have three common components which make it controversial: (1) individuals have different viewpoints, values, biases, and backgrounds, (2) conflict of interests among several number of groups , (3) inadequate evidence (Levinson, 2006).

Related Literature

Limited number of studies has investigated impacts of SSI based instruction intervention on students' CT skills and dispositions. The current study proposes a model and examines its impacts on critical thinking approaches for two main reasons. Firstly, huge body of studies has pointed out how SSI is coherent with instructional goals. However there is less guidance in literature how teachers incorporate SSI in their science classrooms (Sadler et al., 2017; Tidemand & Nielsen, 2017). Existing studies clearly revealed that instructors had lived difficulties in adapting SSI into school science classes (Levinson, 2006; Pitpiorntapin & Topcu, 2016; Sadler et al., 2017; Saunders & Rennie, 2013). They had lack of awareness of the affordances of SSI based instruction (Lazarowitz & Bloch, 2005).

Secondly, many research studies about SSI based instruction have generally focused on students' character, sense of place (Kim, Ko, & Lee 2019), communication skills (Chung, Yoo, Kim, Lee, & Zeidler 2016), science content knowledge (Klosterman & Sadler, 2010), science learning (Zeidler & Nichols, 2009), motivation for science learning (Parchmann, Grasel, Baer, Nentwig, Demuth & Ralle, 2006), epistemological development in science (Zeidler & Nichols, 2009), attitudes toward science (Lee & Erdogan, 2007), reasoning skills (Barab, Sadler, Heiselt, Hickey, & Zucker, 2007), socioscientific reasoning (Sadler, Klosterman, & Topcu, 2011), argumentation (Evagorou & Osborne, 2013), sense of efficacy (Yahaya, Zain, & Karpudewan, 2015), science literacy skills (Romine, Sadler, & Kinslow, 2017), decision making (Wong, Hodson, Kwan & Yung, 2008). However, there are few studies examining the impact of SSI based instruction, curriculum, or framework on critical thinking skills (Zeidler & Nicholos, 2009; Zeidler, Sadler, Applebaum, & Callahan, 2009; Burek, 2012; Cahyarini, Ruhayu, & Yahmin, 2016; Torres & Solbes, 2016; Wang, Chen, Lin, Huang, & Hong, 2017). For example, Zeidler and Nicholos (2009) asserted that the integration of SSI in curriculum provides students to acquire open-mindedness, analytical, and confidentiality about their abilities by solving problem, and making decisions. Torres and Solbes (2016) investigated the effect of SSI-based instructional intervention on the critical thinking skills. The results indicated that this intervention provided students to acquire questioning the scientific information which is essential for critical thinking skills. Wang et al. (2017) revealed that cooperation-driven socio-scientific issue intervention improved students' perceptions of critical thinking. Moreover, integrating SSI into instruction improved higher level thinking abilities of students while making decisions.

The study offers a structured novel SSI based instruction model and aims to investigate its impacts on CT. One essential question is arising from this perspective (1) does the new adapted form of SSI based instruction have a potential to improve critical thinking of PSTs? To find the answer for this research question, this study aims to determine the differences between PSTs in the SSI based instruction group and PSTs in traditional instruction group in terms of CT.

Method

Research Design

Pretest-posttest quasi-experimental design was used as a means of examining how SSI based instruction could impact the critical thinking skills and dispositions. While lack of random assignment into test groups decreases the level of generalizability of the results to a larger population, matching in quasi-experimental design enables to construct a reasonable control group in order to make generalization more feasible (Campbell & Satnley, 2015).

Participants

Convenient groups were assigned to the control group (N: 45) and experimental group (N: 45) in order to conduct research. They are attendants of environmental courses. Both groups had not received any teaching regarding SSI before. Two groups were taught by same teacher who had taught environmental course for six years, and had experiences about SSI based instruction.

The participants were at the ages of 20-22, were enrolled in science education program, willing to participate, were currently available for the study were future science teachers who needs guidance and support about SSI. The study aimed to examine CT of individuals who completed at least 2 years of college science classes; because they had content knowledge about science courses and concepts the accessible population of this study was undergraduate students who enrolled in environmental course. The population was comprised of 90 junior pre-service science students in science teacher education program at the public university in the north of Turkey. Instrumentation

Instrumentation

The Ennis-Weir Critical Thinking Essay Test (E-WCTET)

The Ennis-Weir Critical Thinking Essay Test (E-WCTET) was developed by Ennis and Weir (1985) for measuring critical thinking skills of college level students. This measurement focuses on the dimension of logical reasoning in the process of critical thinking. The purpose of this test is to criticize test takers' arguments by evaluating, analyzing, and inferencing these claims. E-WCTET is an essay test for critical thinking ability. The essay test was written as an article for a fictional newspaper concerning a familiar civic problem of city: parking in the streets. The author offers a suggestion about the issue, and defends the point of view with supportive arguments through eight paragraphs. And then, in the ninth paragraph the author invites citizens to overcome the issue together by criticizing each of eighth paragraphs one by one by evaluating, analyzing, inferencing, and constructing counter arguments or rebuttals.

Aybek (2006) adapted this instrument in Turkish by administering it at the faculty of education to 87 students as a pre and posttest to both experiment and control groups. As a result of administering the E-WCTET. Pearson Correlation Coefficient between groups was found as .90. Moreover, the researcher calculated internal consistency coefficients (Cronbach Alpha) values of pre and post-test as .85 and .88, respectively. In this study, the researcher calculated internal consistency coefficients of pre-test and post-test as .79 and .83, respectively. That means the measurement tool is reliable (see Table 1). Two independent researchers graded students' essay pretest and posttest for interrater reliability.

Table 1. Interrater Reliability of Pretest and Posttest

		Value	Std. Error[a]	Approx. T[b]	Sig.
Measure of Agreement N of Valid Cases	Pretest Kappa	.729 90	.049	28.424	.000
Measure of Agreement N of Valid Cases	Posttest Kappa	.703 90	.050	25.967	.000

California Critical Thinking Disposition Inventory (CCTDI)

This inventory consists of seven sub-scales and 75 items that were defined hypothetically, and were tested psychometrically (Facione, Facione & Giancarlo, 1998). While the internal consistency coefficients of the seven sub-scales vary from .60 to .78, the internal consistency coefficient of the inventory was found as .90 (Kokdemir, 2003). The CCTDI was adapted into Turkish by Kokdemir (2003). He reduced seven sub-scales into six (truth-seeking, open-mindedness, analyticity, systematicity, confidence in reasoning, inquisitiveness), and 75 items into 51. The internal consistency coefficients (alpha) of the sub-scales vary from .61 to .80, the Cronbach alpha was found as .88, and the total variance explained was 36.13% (Kokdemir, 2003). This study also determined the internal consistency coefficients of the subscales between .60 to .85. The Cronbach alpha value of the full scale was found as .83.

In this study, all attendants were asked to rate each CCTDI item using a 5-point Likert scale (5 = strongly agree…1 = strongly disagree). The CCTDI includes 6 factors namely truth-seeking, (7 items min 7– max 35); the second factor is open-mindedness, it included 12 items with a possible total score range of 12–60; the third factor is analyticity, it contained 10 items with a possible total score range of 10–50; the fourth factor is systematicity, it included 6 items with a possible total score range of 6–30; the fifth factor is confidence in reasoning, it contained 7 items with a possible total score range of 7–35; the sixth factor is inquisitiveness, it included 9 items with a possible total score range of 9–45, a sample item is: 'I am always curious to learn science'.

Adapted Form of SSI Based Instruction

The developed model in this study is an amalgam version of SSI based instruction based on the suggestions of Presley, Sickel, Muslu, Johnson, Witzig, Izci and Sadler (2013) (Figure 1), Frederichsen, Sadler, Graham and Brown (2016) (Figure 2), and Sadler, Foulk and Friedrichsen (2017) (Figure 3) with the 5E learning cycle (Trowbridge, Bybee, & Powell, 2008) (see Figure 1,2, and 3). As the beginning section of 5E learning cycle the engagement part is reunited with design elements and encountering focal issue. Design elements offer constructing instruction around a compelling issue as a means of contextualizing the intended subject. Encountering focal issue part provides students to improve awareness of the ways in which science ideas and principles have integrated with social issues. This part also advices instructors to present target subject shortly. Drawing from the studies on SSI, we determined climate change as an ethically, socially, and economically compelling and ill-structured issue because it has not clear-cut solutions (Sadler, 2011; Sadler et al., 2007). Moreover, climate change is a broadly mentioned topic in the media and there are lots of information provided through internet and social media channels. This situation pushes citizens in difficulty to reach reliable and valid information to grasp (Schreiner, Henriksen, & Kirkeby Hansen, 2005). In addition, Clark, Ranney, and Felipe (2013) stated that students should be educated about interdisciplinary complexity societal, and ethical causes and consequences of climate change.

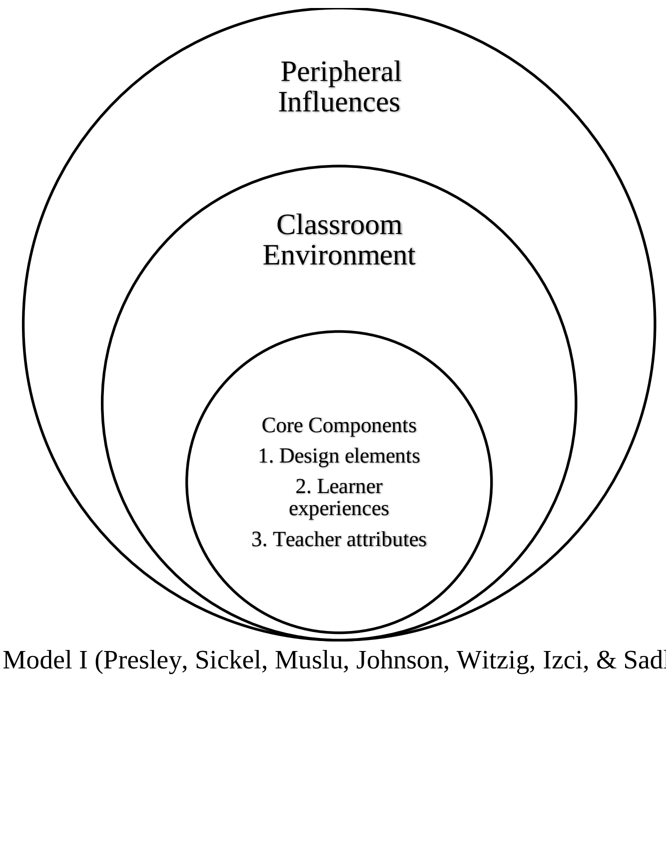

Figure 1. Model I (Presley, Sickel, Muslu, Johnson, Witzig, Izci, & Sadler, 2013)

Exploration part is combined with design elements, learner experiences, three dimensional science learning, and social interaction. Learner experiences expect students to gather and analyze data, and want them to compare opponent ideas about the subject considering social, economic, and ethical dimensions. Moreover, this dimension called for students to negotiate different perspectives, scientific ideas, and theories. Three dimensional science learning anticipates students to engage in disciplinary core ideas, crosscutting concepts, and science practices. Disciplinary core ideas corresponded to carbon cycle and greenhouse gases in climate change unit. Crosscutting concepts addressed in climate change related to stability and change, causes and effects, and solutions. Science practices involves asking questions, defining problems, planning and carrying out investigations, obtaining, evaluating, and communicating information, and constructing explanations (Sadler et al., 2017). Social interaction dimension demands students to negotiate compelling focal issue considering the social complexities of it. Explanation part is enriched by learner experiences, teacher attributes, and peripheral influences. These attributes ask teachers to be familiar with SSI, to realize social dimensions, and to have adequate content knowledge. Peripheral influences demand a flexible curriculum to encourage instructors who wish teaching SSI. This part also expects having adequate SSI based teaching materials. Elaboration part is detailed with design elements, learner experiences, higher order experiences, and socio-scientific reasoning. All three aim to target improving higher order thinking skills via reasoning, discussion, and taking positions as an opponent or advocate in this part. Evaluation part is culminated with learner experiences, synthesis of ideas and practices, and additional elements. The second one asked for students to synthesize ideas and practices they engaged throughout the climate change unit. In the current study, PSTs wrote a decision making essay whether they believe or not to climate change by making recommendations considering scientific ideas and others' perspectives they encountered. The third one expects students to give feedbacks to their friends' arguments, counter arguments, and rebuttals. In this study, PSTs made peer-assessment by examining the arguments, counter arguments, and the rebuttals of group mate for supporting peer interaction

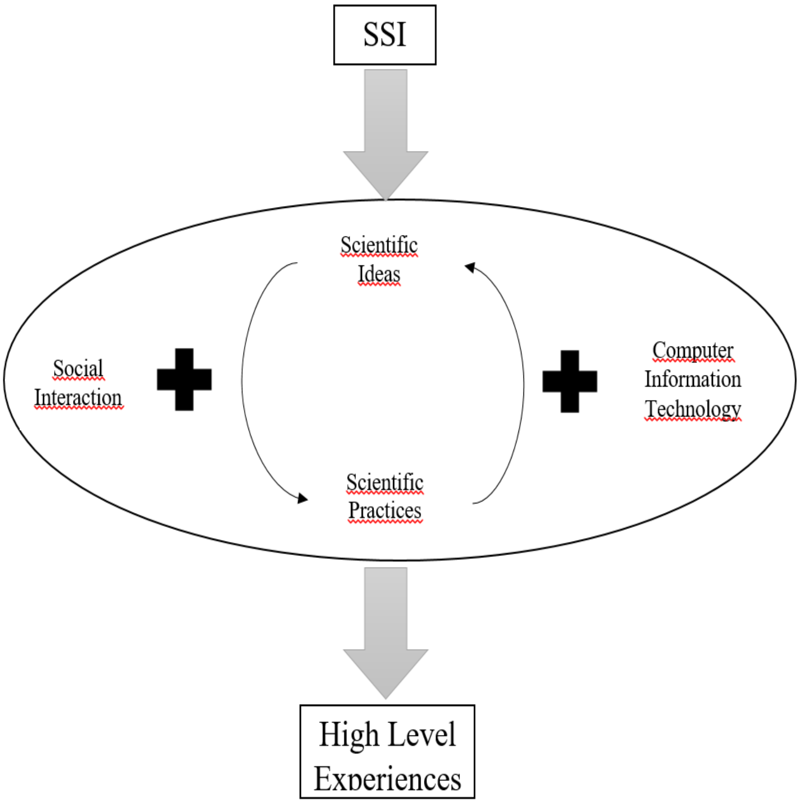

Figure 2. Model II (Frederichsen, Sadler, Graham and Brown, 2016)

The new form also enables opportunities of ethical understandings by constructing classroom environment. As an example, with the help of this instruction, students gain empathy towards themselves and environment, they obtain open-mindedness while changing their decisions, and they approach controversial issues with responsibility and virtue. Moreover, the form contributes Presley et al.'s (2013) study to gain the ability of socioscientific reasoning which includes sub-dimensions of realizing the complex structure, investigating the multiple perspectives, accepting the questioning-based side, and acting with suspicion towards bias-based knowledge. In complexity dimension, teachers expect students to avoid from simple and linear solutions. In multiple perspective side, teachers want students to analyze the issue by combining the same and opposite ideas. In questioning-based dimension, teacher proposes student to make more investigations and research about these issues. In skepticism side, teachers suggest students to examine the credibility, validity, and reliability of scientific knowledge.

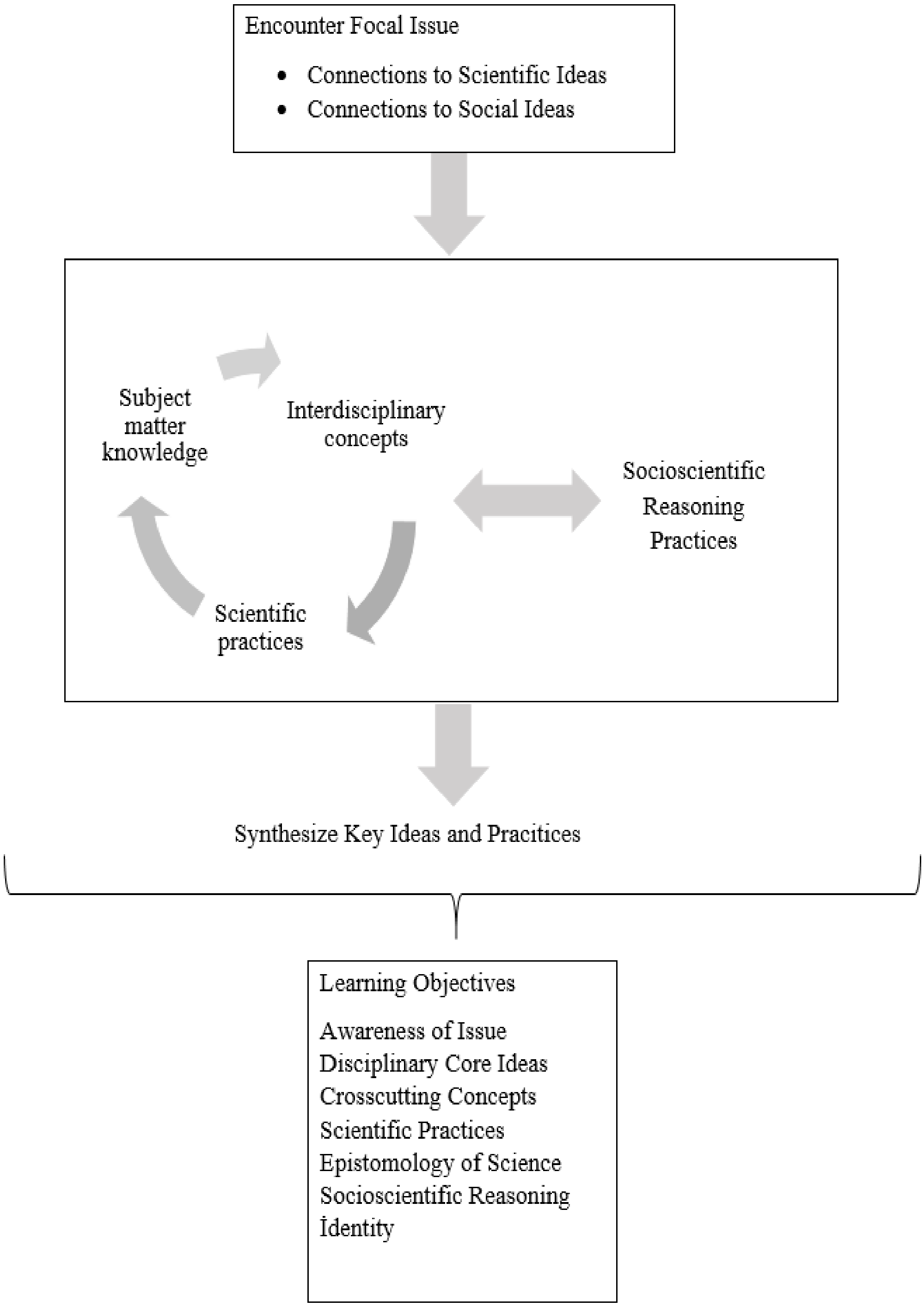

Figure 3. Model III (Sadler, Foulk, & Freidrichsen, 2017)

This design aims to support and guide the students in developing knowledge, skills, and attitudes to cope with SSI in their lives and to construct informed thoughts on emerging science and technology issues. Moreover, this adapted model aims to provide students with applying scientific knowledge and enhancing a reasoned decision making (Pedretti & Nazir, 2011). Additionally, the 5E learning cycle was used as an instructional model in the design of existing SSI based instruction because it is a constructivist student-centered approach engaging students in science learning, and encouraging them in their learning process.

Table 2. The SSI based Instruction Framework (Adapted from Presley et al., 2013; Frederichsen et al., 2016; and Sadler, Foulk & Friedrichsen, 2017)

Classroom Environment (1) high level of the participation of the students, (2) collaborative and interactive environment, (3) respectful behaviors among students and teacher, (4) sense of confidence among students and teacher, (5) composing an environment that is suitable for negotiating economic, social, and political dimension of the issue, (6) access to SSI-based materials, (7) suitable environment for negotiating economic, social, and political dimension of the issue	5E Teaching Model	SSI-Based Instruction
	Engagement	1. Design Elements (Model I) 1.1. Building lesson around compelling issue (Model I and III) 1.2. Presenting issue in real world context (I, II, and III) 1.3. Using computer information technology-media (I and II)
	Exploration	1. Design Elements (Model I) 1.4. Presenting scaffolding like decision making, argumentation (II and III) 1.5. Presenting active learning experiences like role play, discussion, peer interaction (I, II, and III) 2. Learner experiences (Model I) 2.1. Providing students to engage with higher order practices (II and III) 2.3. Ensuring them to gather and analyze data concerned with the issue (I and II)
	Explanation	2. Learner experiences (Model I) 2.2. Enabling them to encounter scientific ideas and theories regarding the issue. ((I, II, and III) 3. Teacher attributes (Model I) 3.1. Teacher should have mastery about the issue (I) 3.2. Teacher should be honest about knowledge limitations (I) 4. Peripheral influences (Model I) 4.1. Flexibility of curriculum that provides teachers to accommodate SSI-based instruction (I) 4.2. Connecting SSI-based curricula with state- or national level curriculum objectives. (I, II, and III)
	Elaboration	1. Design Elements (Model I) 1.4. Presenting scaffolding like decision making, argumentation (II and III) 1.5. Presenting active learning experiences like role play, discussion, peer interaction (I, II, and III) 2. Learner experiences (Model I) 2.1. Providing students to engage with higher order practices (II and III) 2.3. Ensuring them to gather and analyze data concerned with the issue. (I and II)
	Evaluation	1. Design Elements (Model I) 4.1. Presenting scaffolding like decision making, argumentation (II and III) 5. Learner experiences (Model I) 5.1. Providing students to engage with higher order practices -Decision making essays, policy, recommendations, constructing scientific arguments, theories. (II and III)

Procedure

The process was shown below at Table 3 in time sequence.

Table 3. Sequence of SSI Based Instruction

Week		SSI Based Instruction Experiences
1	A.	Students completed the CCTDI and E-WCTET as a pretest.
	B.	The lesson was set around a compelling socioscientific issue: climate change as a focal issue. The teacher started to lecture with an interesting question and activity sheet in order to get the participants' attention and to link subject into real world context as an engagement part. The question arises from daily life: Can you decrease the effects climate change by not making barbecue? The students answered the question variously, and the teacher directed small discussions among them in order to provide scaffolding for higher order practices. Students remembered prior knowledge via small discussions. Then, the teacher made a hands-on-activity about carbon footprint calculation via an online tool to enable them a culminating experience about climate change. Culminating exercise provides students to synthesize their prior knowledge with the focal issue including science ideas and practices, social connections, and information communication technology.
	C.	Efficient and relevant material is important for engagement part (Bybee 2014). In this way, the students discussed about how they can make carbon footprint smaller by giving examples from their daily lives.
	D.	Then, the teacher divided students into five heterogenic research groups concerning jigsaw method (Aronson and Patnoe 2011). Each research group was appointed with different pattern of climate change: causes, effects, evidences, solutions, and the opponents of climate change. Each group member took on different responsibilities of in order to provide positive interdependency among them. For instance, in effect group, every member focused on another dimension such as economic, social, ethical, and health impacts.
2	A.	As an exploration part, each group made research by using sources like NASA, evidence based news from newspapers, films and documentaries, Health Department, United Nations Framework Convention on Climate Change (UNFCCC), World Bank, Intergovernmental Panel on Climate Change (IPCC), and United Nations Environment Program (UNEP), Food and Agricultural Organization (FAO), and United Nations (UN) in the classroom. This enabled active learning experiences for the students. In this way, students encountered disciplinary core ideas and crosscutting concepts about climate change. During this process, teacher provided guidance about data sources.
	B.	Each member from different groups (causes, effects, evidences, solutions, and opponents) has gathered and delivered presentation to others by using computer information technologies. Thus, they engaged in science practices such as planning and carrying out investigations, obtaining, evaluating, and communicating information. Other group members discussed and took notes. All data sets like bar and line graphs, pie charts, short videos, animated gifs, before and after photos, and demographics from these reliable sources were shared each other via Google drive.
3	A.	The teacher explained scientific ideas and theories of climate change of opponents and advocate groups in an explanation part.
	B.	In an elaboration part, each group member turned back their original group, analyzed and discussed shared data sets as an element of socioscientific reasoning. Then, they prepared final presentations with holistic approach to make decision whether climate change exists or not. They focused on social, political, economic, and ethical issues like industrialization, international agreements, and immigrants, threats about tourism, energy supply, employment, clean drinking water, foods, health issues, and extinction of species. While each group was delivering their presentations, they made small discussions with the help of the teachers' instruction. In this way, the students engaged in higher-order practices by making discussions. They met scientific ideas about climate change. And they negotiated social and ethical dimensions of the issue.
4	A.	In evaluation part, PSTs wrote a decision making essay whether they believe or not to climate change by synthesizing arguments, counter arguments, and rebuttals as acting like a governor, a famous person, a media director, a civil society director, or a factory owner. Thus, the students again were exposed to a higher order practice like decision making and socioscientific argumentation.
5	A.	The teacher divided PSTs into groups of two. Every person of the group made peer-assessment by examining the arguments, counter arguments, and the rebuttals of group mate for supporting peer interaction. Then, the group member made some suggestions about the essay of group mate as an additional element.
	B.	Students completed the CCTDI and the E-WCTET as a posttest.

Data Analysis

Before applying descriptive statistical analysis, the researcher tested two general statistical assumptions respectively; normality and variance of participating groups. Descriptive statistics and further analyses were used to describe the groups being studied individually and in total. Basics statistics (Mins, Maxs, SD, and Frequencies) were used for revealing the demographic characteristics of the participating groups. The differences between the means of pretests and posttests were compared across groups to determine the impacts of SSI based instruction on the critical thinking. The .05 level of significance was selected as the p value for rejection of the null hypotheses. Analysis of covariance (ANCOVA) was used for the comparisons of the means in order to determine if there were any statistical significant differences in critical thinking. The pre-test scores of the E-WCTET and the CCTDI was taken as a covariate, the post-test scores of E-WCTET and CCTDI was included as dependent variable, and the method of instruction was the independent variable (i.e direct instruction group vs. SSI-based instruction group). In this study, the researcher used also eta squared (0.01 small effect size, 0.09 medium effect size, and 0.25 large effect size) in order to investigate the magnitude of the effect size of intervention on the PSTs' critical thinking skills and dispositions.

Results

The normality of E-WCTET and CCTDI was examined by Kalmogorov-Smirnov normality test. The results that the data have a normal distribution (*p*=.412 for E-WCTET; *p*=.601 for CCTDI) (see Table 4).

Table 4. The SSI-based Instruction and the Direct Instruction Groups' E-WCTET and CCTDI Normality Test Results

	Treatment	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
E-WCTET	SSI	.104	46	.200*	.975	46	.412
	Control	.109	44	.200*	.981	44	.684
CCTDI	Treatment	.118	45	.127	.980	45	.601
	Control	.084	45	.200*	.977	45	.499

*p>.05

The homogeneity of variance test was examined by Levene's Test. The results showed that the within group variances were similar (F test *p*=0.475 for E-WCTET; *p*=0.915 for CCTDI) (see Table 5).

Table 5. The SSI-based Instruction and the Direct Instruction Groups' the E-WCTET and CCTDI Homogeneity Test Results

Dependent Variable: Posttest

	F	df1	df2	Sig.
E-WCTET	.515	1	88	.475*
CCTDI	.012	1	88	.915*

An ANCOVA test was conducted to determine the significant difference between the treatment and the control group in terms of their critical thinking skills (F(1.90) = 1.84, $p > .05$ $n_p^2 = .021$) as shown in Table 7. The results indicated that SSI based instruction in the treatment group had no significant impact on critical thinking skills. However, descriptive statistics showed that there was an increase in mean scores of treatment group (Mpre=4.50, Mpost=6.04) (see Table 6). The researcher also calculated the effect size ($n_p^2 = .021$) of the intervention. It means the intervention had small effect size.

Table 6. Means and Standard Deviations of the E-WCTET Pre-test and Post-test Scores

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
Pretest	SSI	46	4.5000	5.60060	.82576
	Control	44	4.5000	4.97201	.74956
Posttest	SSI	46	6.0435	4.93494	.72762
	Control	44	4.5455	5.95508	.89776

Table 7. The Effects of SSI-based Instruction on the E-WCTET Scores

Dependent Variable: Posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	296.335[a]	2	148.167	5.428	.006	.111
Intercept	778.410	1	778.410	28.515	.000	.247
Pretest	245.868	1	245.868	9.007	.004	.094
Treatment	50.467	1	50.467	1.849	.177	.021
Error	2374.954	87	27.298			
Total	5210.000	90				
Corrected Total	2671.289	89				

An ANCOVA test was conducted to examine the significant difference between the treatment and the control group in terms of their critical thinking dispositions after the intervention of SSI-based instruction (F(1.90) = 22.5, $p< .05$, $n_p^2= .206$) as shown in Table 9. The results indicated that the intervention had significant impact on critical thinking dispositions. Moreover, there was also an increase in the scores of the treatment group after the intervention (Spre=187.2, Spost=202.2) (see Table 8). The researcher also calculated the effect size (the Cohen's *d*=1.18) of the intervention.it means the intervention had high effect size. Partial eta squared value ($n_p^2= .206$) also indicated that the intervention had high effect size.

Table 8. Means and Standard Deviations of the CCTDI Pre-test and Post-test Scores

		N	Mean	Std. Deviation	Std. Error Mean
Pre-test	Treatment	45	187.2000	17.45592	2.60217
	Control	45	180.7556	20.60247	3.07123
Post-test	Treatment	45	202.2889	16.33126	2.43452
	Control	45	185.1556	17.24681	2.57100

Subscales of critical thinking dispositions were also examined by conducting separate ANCOVA for systematicity, confidence in reasoning, analyticity, inquisitiveness, truth-seeking, and open-mindedness. Effects sizes were calculated by using partial eta squared.

Table 9. The Effects of SSI-based Instruction on the CCTDI Scores

Dependent Variable: Post-test					
Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2	7765.145	42.495	.000	.494
Intercept	1	8768.392	47.985	.000	.355
Pre-test	1	8925.390	48.844	.000	.360
Treatment	1	4124.069	22.569	.000	.206
Error	87	182.733			

Results of ANCOVA for systematicity subscale showed that there was a significant mean difference between experimental and control group (F(1.90) =9.05, $p< .05$) the treatment had middle size effect on the systematicity (Partial $n_p^2= .09$) (see Table 10). There is a significant difference (F(1.90) =12.98, $p< .05$ Partial $n_p^2= .130$) between the control and the treatment group at the subscale of confidence in reasoning while controlling the effect of pretest. The partial $n_p^2= .130$ was calculated by looking at the means and standard deviations' scores (see Table 10).

It explains that the treatment had middle size effect on confidence in reasoning. The analyticity scores were analyzed at the Table 10, (F(1.90)=12.39, $p< .05$ Partial $\mu^2= .125$), it means the treatment have significant impact. The partial eta squared (.206) states that the intervention had middle size effect. The inquisitiveness scores were analyzed at the Table 11, (F(1.90)=18.67, $p< .05$ Partial $\mu^2= .177$), it shows that the treatment have significant impact on inquisitiveness. The partial eta squared (.177) states that the intervention had middle size effect.

Table 10. ANCOVA Test Results of Disposition Subscales for the Effects of SSI-based Instruction on the CCTDI

Subscales		Mean Square	F	Sig.	Eta Square
Systematicity	Pre-test	7.472	19.729	.000	.185
	Treatment	3.431	9.058	.003	.094
Confidence in Reasoning	Pre-test	13.467	42.087	.000	.326
	Treatment	4.156	12.987	.001	.130
Analyticity	Pre-test	5.913	23.035	.000	.209
	Treatment	3.182	12.397	.001	.125
Inquisitiveness	Pre-test	25.859	85.444	.000	.495
	Treatment	5.651	18.673	.000	.177
Truth-seeking	Pre-test	5.831	22.841	.000	.208
	Treatment	.602	2.359	.128	.026
Open-mindedness	Pre-test	15.572	78.691	.000	.475
	Treatment	1.931	9.759	.002	.101

As pointed out at the Table 10, there is no significant difference (F(1.90)=2.3, $p>.05$ Partial $\mu^2= .026$) between the control and the experiment group at the subscale of truth-seeking. The partial eta squared (.026) implies that the intervention had small size effect. The subscale of open-mindedness (F(1.90) =9.75, $p<.05$ Partial $\mu^2= .101$) scores was analyzed, so that the intervention have significant impact on open-mindedness. The Cohen's d (.72) value and partial eta squared (.101) indicates that the intervention had middle size effect.

Discussion

The purpose of the current study was to examine the impacts of the new adapted form of SSI based instruction framework on the PSTs' critical thinking skills and dispositions in climate change unit. The limited number of existing studies investigating the impacts of SSI based instruction framework on critical thinking led the researcher to discuss the study in itself, and with studies conducted SSI based interventions. The results indicated there was not statistically significant difference between experimental and control groups in terms of critical thinking skills. However, they revealed that the treatment group showed increased in the posttest scores of the E-WCTET, and scored higher than the control group. On the contrary, the results descriptive statistics analysis indicated that there was a statistically significant difference between two groups' critical thinking dispositions, especially at the subscale of systematicity, analyticity, confidence in reasoning, inquisitiveness, and open-mindedness except the subscale of truth-seeking.

The former descriptive findings obtained from E-WCTET indicated that the treatment group's posttest scores were improved. This result could be originated from some properties of SSI based instruction framework. Firstly, the SSI based instruction framework uses authentic tasks in real world context. Berge, Ramaekers, and Pilot (2004) stated that authentic problem tasks have the characteristics of ill-structured, open-ended, multiple answers in real life contexts. Previous studies revealed that using authentic tasks improved higher order thinking skills, provided individuals to be engaged in critical thinking processes (Brown, Collins, & Duguid, 1989. Moreover, Chowning (2009) claimed that integrating real world problems (climate change) into school science classes improves critical thinking. Secondly, the SSI based instruction framework proposes using decision making and discussion as a scaffolding in order to improve higher order thinking. The study of Kim, Sharma, Land, and Furlong (2013) stated that using these types of scaffoldings had significant effect on critical thinking skills. Thirdly, the new model consists of the patterns of collaborative teaching, interactive environment, peer-interaction, and negotiating in classroom environment part. Groups were constructed with principles of heterogeneity and positive interdependency. The study of Yuretich (2003), Abrami, Bernard, Borokhovski, Wade, Surkes, Tamim, and Zhang (2008) asserted that using collaborative and cooperative learning increased critical thinking skills significantly. Wang, Chen, Lin, Huang, and Hong (2017) claimed that nature of SSI enables students to study in supportive, interactive, and reflective learning environment which enhances CT because this model presents students democratic settings in which they do not feel any personal competition or blaming.

Moreover, nature of new SSI based instruction may bring about this increase because it includes science practices like planning and carrying out investigations. This practicing may improve scores of CT. Sadler and Donnelly (2006) also stated that the nature of SSI was exposed students to multifaceted perspectives and questions through peer interaction and discussions leads them to improve CT. Using SSI in school science developed students reflective thinking (Sadler & Zeidler, 2005). As recommended by Dawson and Carson

(2018), if the teacher integrates an authentic context into classroom (climate change), it provides an explicit guidance to classroom dialogue (whole class and small group) and use scaffolding (decision making essay), this instruction enhances students' thinking. The new model was constructed upon nature of SSI and meets all necessities. Therefore, the treatment group increased the posttest scores of CT skills.

The descriptive findings of the CCTDI showed that there was a statistical significant difference between the control and the treatment group. According to Paul (1995), disposition is emotional side of critical thinking and important for increasing critical thinking skills? Emotions are considered as key elements for increasing any skills related to education (Abu Karsh, 2018; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011; Uhomoibhi & Ross, 2018). Concerning the subscales of critical thinking dispositions, the study revealed that inquisitiveness of individuals improved because this adapted SSI framework begins lesson with a compelling issue which gets attention of students and SSI presents ill-structured and non-clear-cut solutions which trigger curiosity. This argument is consistent with the findings of by study of Zeidler et al. (2011) and Dori, Tal, and Tsashu (2003). The former study claimed that SSI intervention provides students to become more curios, to show good judgments, to gain confidence in reasoning while engaged in open-ended, ill-structured problems. The latter study examined the impacts of SSI intervention on students' interest. They found that students' interest towards socially embedded science issues increased after the intervention clearly. Lee and Erdoğan (2007) asserted that using SSI improved positive attitudes towards science and learning. Studies on SSI showed that students gained awareness of their role in society when evaluating a scientific claim with regard to its reliability (Kolsto, 2006; Sadler, 2009). Moreover, the participants wanted to see more examples about SSI. The pattern of interest and curiosity is aligned with inquisitiveness subscale.

This study also showed that open-mindedness and confidence in reasoning of students developed. Being encountering with possible solutions of ill-structured problems, comprehending how others feel and react in various situations impact these two dimensions (Herman, Zeidler, & Newton 2018). This effect stems from attributes of collaborative learning (CL) embedded in SSI based instruction framework. CL provides students to share ideas, arguments, counter arguments, and rebuttals without feeling any judgments. Thus, this environment leads students to work and seek actively for finding meaningful solutions and constructing reliable knowledge (Wang et al., 2017, Johnson & Johnson, 2003). In addition, students socially construct arguments and claims in CL environment which increases socialization across students and then socialization leads students to more open-mindedness (Wang et al., 2017). Chung et al. (2014) claimed that SSI presents a classroom environment where students express their ideas and feelings freely about controversial issues. This science school classroom improved the ability to value others' ideas as an open-mindedness one. Chung et al. (2014) stated that this development is stem from nature of SSI which is complex and no clear cut answer. Lacking definite solution may lead students to being open to different thoughts in order to make well informed decisions. Moreover, when individuals feel comfortable while presenting their viewpoints, they also show willingness to accept another's viewpoint without judging (Wu & Tsai, 2007). This outcome is supported by the study of Dawson and Venville (2010). They investigated impacts of SSI intervention on CT. Results showed that the intervention group made better judgments, and behaved more respectful to others' positions. Students revealed a big interest and deep comprehension towards science concepts, and they made more confidential and meaningful decisions about their health and environmental problems (Dolan, Nichols, & Zeidler, 2009). These results clearly reflect the properties of confidence in reasoning and open-mindedness subscale because open-mindedness was defined as having tolerance to others' views and confidence in reasoning was defined as making good judgments by trusting one's own reasoning (Facione, 1992).

Thirdly, this research indicated that students' analyticity and systematicity in SSI based classroom enhanced. This might be originated from the pattern of SSI based instruction which provides students to gather data from web based sources, information-rich and knowledge-oriented society by classification, and analyzing data by using graphics and tables (Wu & Tsai, 2007; Wang et al., 2017). In addition to this, new instruction model enriches classroom environment by presenting students to synthesize ideas and practices, and to give feedbacks to their friends' arguments, counter arguments, and rebuttals. These acquisitions may develop CT skills. Also, Dolan, Zeidler, and Nichols (2009) asserted that using SSI enable students to become more analytical, and support them to use inquiry skills.

Finally, the findings about truth-seeking disposition revealed that there was no significant difference between control and treatment group. This may be stem from teacher's 's guidance because while participants were preparing the presentations, the researcher wanted them to use authoritative sources like NASA, UNFCCC, IPCC, UNEP, FAO, and UN. This situation may lead participants not eager to be to seek truth, because they knew that the sources were reliable. Thus, the researcher advocates that if the teachers want to develop students' truth-seeking disposition, they may not lead the students to reach reliable and valid information sources directly.

In short, current study claims that SSI based instruction framework may students to practice listening to group members (i.e. open-mindedness and inquisitiveness), provide feedbacks on peers' comments (i.e. analyticity and systematicity), and to try to reach consensus within their team (i.e. truth-seeking). Consequently, students become more confident (i.e. self-confidence) about their CT skills (Wang et al., 2017). The current study adds value to the literature by proposing a new model to SSI based instruction because previous studies addressed a gap in the literature that PSTs, as a future instructor, lack a structured and detailed model to guide them. Moreover, if the new model one helps them to improve their CT to make well-informed and reasonable decisions by analyzing, evaluating, and inferencing, PSTs may also support their students to enhance CT. Our findings clearly showed that the model plays an important role in enriching CT skills and dispositions.

Critical thinker has specific personality attributes, dispositions, and attitudes (Ennis, 1987; Facione, 1990). Paul (1984) asserted that critical thinker has attitudes and dispositions together. All these definitions about the critical thinker indicate that there is a strong relationship between critical thinking and critical thinking dispositions. For example, Facione and Facione (1992) investigated the correlation between the college students' dispositions and skills by administering the California Critical Thinking Test and the California Critical Thinking Disposition Inventory. The findings revealed that there was a strong relationship between skills and dispositions (r =.67). The study pointed out that context of the new adapted model of SSI-based instruction has a strong potential to improve critical thinking skills. The study claims that improving he pre-service teachers the critical thinking dispositions may lead us to enhance critical thinking skills of them. According to Facione and Facione (1993), if a person has a tendency towards a skill, then person has the aptitude to execute the skill. That is, having a cognitive disposition contributes to displaying a cognitive skill by exercising appropriately.

Notes

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