Promoting students' critical thinking and scientific attitudes through socio-scientific issues-based flipped classroom

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Science and technology are developing rapidly, causing changes in teaching modes based on different needs and situations. This study aims to determine the effect of the flipped classroom model, integrated with the socio-scientific issues (FCM-SSI) on critical thinking skills and scientific attitudes of junior high school students on additive and addictive substances and to determine the differences in each aspect of critical thinking skills and scientific attitudes after intervention with FCM-SSI. Through quasi-experimental research with a pretest-posttest design, 182 students participated as samples. The experimental group had 91 students exposed to the FCM-SSI, and the control group had 91 students with traditional learning. For data collection, critical thinking skills test with essay questions and a scientific attitude test using a scientific attitude scale were used. Data were analyzed using MANOVA to see the effects of the learning model and ANOVA to see differences in each aspect. The statistical analysis results with a value of sig 0.000 ≤ 0.05 indicate that FCM-SSI affects students' critical thinking skills and scientific attitudes. The most influential aspect of critical thinking skills is the analytical aspect, and openness is the most influential aspect of scientific attitude. Thus, the FCM-SSI model is highly recommended to be used in science learning because it can improve students' critical thinking skills and scientific attitudes.

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1 Introduction

The Sustainable Development Goals (SDGs)'s general nature requires commitment from all social order actors, such as teachers working in the education sector. Teachers play an essential role, both through their actions and in the way they teach students. Teachers must contribute to the sustainability of education by using technology in learning, such as e-learning (Chen, 2021). New innovative technologies and e-learning platforms have been integrated into all levels of education, including science learning. New innovative technologies and e-learning platforms have been integrated into all levels of education, providing support to teachers and students (Lee & Park, 2018). This e-learning platform has expanded boundaries in teaching and learning activities, such as the limitations of time and traditional classrooms and the creation of new learning delivery methods, such as the flipped classroom model (Jdaitawi, 2019). The flipped classroom model (FCM) has become a popular and most effective approach for carrying out the reforms needed in educational technology and has been used by some academic units (Ayçiçek & Yelken, 2018; Strelan et al., 2020; Bishop et al., 2013; Hao, 2016. FCM is a learning model where activities traditionally carried out in the classroom (e.g., content presentation) become activities at home, and activities that are usually homework become activities in the classroom (Bergmann & Sams, 2012). The concept of FCM is that students read or watch learning materials at home using a learning platform to learn the material (Quint, 2015). Because students have studied the material at home by watching and learning videos provided through digital platforms, that class time is used more for problem-solving and work that is more practical and participatory (Palazón-Herrera & Soria-Vílchez, 2021).

Learning science will be more meaningful if using contextual learning. With contextual learning, students are allowed to construct relationships in contexts that are more relevant and meaningful to them in the problem-solving process, which in turn it will lead to an increase in students' thinking skills, such as skills in making conclusions, analyzing, synthesizing, and evaluating (Suryawati & Osman, 2018). On the other hand, Socio-scientific issues (SSI) contains contextual and current events in the community, so it makes students more excited to learn (Karakaş, 2022) since the science relevant to students' life be promoted (Owens et al., 2019; Sadler et al., 2016; Sadler & Zeidler, 2004; Wiyarsi et al., 2021). The SSI is a controversial scientific topic but has an additional element that requires moral reasoning or evaluation of ethical issues in the decision-making process regarding possible problem-solving (Sadler, 2004; Zeidler & Sadler, 2007; Zeidler & Nicols, 2009). SSI is described as an issue or problem that has a conceptual relationship with science but cannot be solved through understanding science alone because these issues are socially relevant and very specific (Owens et al., 2019; Yahaya et al., 2016). Controversial topics in SSI are essential in science education because they are used as tools in science learning to be more relevant, a vehicle for students to appreciate the nature of science (NOS), increase argumentation in discussions, improve the ability to evaluate scientific data and information, and include essential aspects in scientific literacy (Sadler & Zeidler, 2004). Therefore, in this study, FCM will be combined with SSI in science learning.

In the Indonesian context, junior high school students learn science through integrated science as the compulsory subject that is considered an essential foundation for forming quality human resources (Rusilowati et al., 2016). Integrated Science subject covers various topics in physics, biology, chemistry, earth, and space (Insani, 2016). Potential SSI materials include acids and bases, environmental pollution, global warming, biodiversity, genetics, additives, and addictive substances. These topics are related and needed by students to understand various problems in their life, including SSI problems, especially for local SSI in the Indonesian context, such as vaccination, volcanoes, nutrition, overhead power lines, alternative medicine, forests, biodiversity, energy sources, coral reefs, water sources, alcohol use for medical, family planning, and tourism in historical places (Wiyarsi & Çalik, 2019). For instance, SSI about fossil fuel is related to the Energy concept (Dishadewi et al., 2020) for students in grade 7th, and nutrition as SSI with a focus on the use of borax (Wiyarsi et al., 2021) is related to Addictive concept for 8th-grade students.

The issues about additives and addictive substances are immediate attention in Indonesia since there are many cases of abuse, for example, the misuse of dyes and preservatives in food and beverages and the use of drugs and alcohol that potentially ruin the young generation. In addition, the issue of additives and addictive substances is one of the social challenges in sustainable development, namely poor lifestyle choices, including the consumption of harmful products such as tobacco, alcohol, and fast food (Greenland et al., 2022). Consumption of harmful products drives the leading cause of chronic disease and death worldwide (Moodie et al., 2013). Thus, these issues are closely related to students' daily lives and are essential for them to understand well to make the appropriate decision. Hence, involvement in SSI issues during learning additive and addictive topics triggers students to apply scientific concepts, principles, and practices to these issues, which are also influenced by social, political, ethical, and economic considerations.

One of the main objectives of learning science is to build critical thinking skills (Jenkins, 2011). In addition, critical thinking is also one of the essential skills and knowledge that students must prioritize in the 21st century (Duran & Sendag, 2012; Scott, 2015). Critical thinking is a high-level skill that allows a person to make decisions and take appropriate actions (Ennis, 2013). It can help students become independent and proficient in problem-solving (Zubaidah et al., 2018). Being able to think critically is a powerful predictor of academic achievement in children and adults and successful life decisions in general (Bellaera et al., 2021). The practice of critical thinking in science learning reaps several problems. Among them are revealed in the research (Santos, 2017) explaining the relevance and strong relationship between critical thinking and science education, but problems were found when applying critical thinking in science classes, namely the lack of clarity in using essential thinking techniques in class on science subjects. In addition, Nuryanti et al. (2018) on critical thinking analysis in Junior High Schools (show that students' critical thinking skills are low. The low critical thinking ability of students can also be seen from the results of the Program for International Student Assessment (PISA). The 2018 PISA results in science show that students in Indonesia scored lower, which is around 40% of the OECD average in science of 78% (OECD, 2019).

In addition to critical thinking skills as students' cognitive abilities in learning science, developing a scientific attitude is also an important goal of the school curriculum (Fitriani et al., 2020). Scientific attitude is the ability of students to react consistently, rationally, and objectively in a certain way to a new situation or problem (Olasehinde & Olatoye, 2014). Thus, attitude is essential in influencing students' behavior and is very important in science learning (Fitriani et al., 2020). Students need to learn to appreciate science, develop an interest in science, and build a positive view of science (Bertling et al., 2016). Previous studies show a relationship between the science learning environment and students' attitudes toward science (Aldridge, 2000). Another study concluded that the scientific attitude of 8th-grade students is still in the low category (Khuserawati et al., 2020; Rahman et al., 2017). Therefore, developing students' scientific attitudes through an appropriate learning environment is necessary.

Consequently, the flipped classroom model, integrated with the socio-scientific issues (FCM-SSI), is essential to this topic to extend the science learning strategy. FCM-SSI learning model will be first carried out at home by presenting learning videos containing SSI material content and issues to be taught and then continued at school by discussing SSI issues together. This present study is expected to be a reference and choice for teachers, especially junior high school science teachers, in choosing learning models relevant to student's daily lives and based on information technology to be applied in science learning in junior high schools. Therefore, this study aims to determine the effect of the FCM-SSI model on the critical thinking skills and scientific attitudes of junior high school students and is focused on answering the following research questions.

- Is there a significant effect of the FCM-SSI learning model on students' critical thinking skills and scientific attitudes?
- How are the differences in each aspect of students' critical thinking skills and scientific attitudes after the implementation of the FCM-SSI model?

2 Methods

2.1 Research design

This study used quasi-experimental research with a pretest-posttest design. One group was used as the experimental group, and the other as the control class. The experimental group was taught using the FCM-SSI model, while the control group was taught using the traditional approach, especially with lectures. Critical thinking skills and scientific attitudes were measured before and after the FCM-SSI teaching intervention.

2.2 Research sample

Students in 8th grade from three Public junior schools in Central Java, Indonesia, were taken as research samples. The selection of the research sample was carried out in two stages of cluster sampling. The first stage aims to randomly select junior high schools in the district and select three junior high schools, each consisting of seven classes in the eighth grade. Thus, the second stage of random cluster sampling determines the classes used as the experimental and control classes. Based on the results of observations and interviews, all classes have the same characteristics in science learning, so all classes had the same opportunity to be sampled. Thus, two classes were randomly selected for each school with a total sample of 182 students, consisting of 91 students in the experimental class and 91 in the control class. Participants were, on average, 13-14 years old and were in grade 8 for the 2021/2022 academic year.

2.3 Treatments

This research was conducted in three meetings on additives and addictive substances, both in the experimental and control classes. In the experimental class, the intervention with online learning for initial observation and orientation of controversial issues (see Table 1) is given to students a maximum of three days before learning in class so that students can manage their time for an online intervention. Online intervention learns the material through learning videos uploaded on the Moodle platform. This learning video also contains SSI issues which will later become a topic of discussion in offline learning. If there is the material that students need help understanding, it can be written on the worksheet that has been given. Students also answer questions about SSI issues in the learning video through existing worksheets. Questions related to SSI issues are provided as a guide for students to argue in class discussions. SSI topics in each intervention, namely: a) the first meeting, namely the action of Portugal captain Cristiano Ronaldo (CR-7) shifting two bottles of Coca-Cola (soda); b) the second meeting, namely the discovery of foods containing formaldehyde and rhodamine B and; c) the third meeting of drug abuse in Indonesia. Offline intervention, the first time done is feedback from learning videos; through this activity, students learn material that has yet to be understood. Next is a student organization, which divides discussion groups. Then proceed with arguments against existing controversial issues, making related decisions, and students are asked to conclude the problem-solving results from the issues given (see Table 1). The control class was conducted without online learning and SSI topics, but the learning materials and the number of meetings were the same. The control class uses a scientific approach commonly used in junior high school science learning in Indonesia.

Table 1. Syntax of the Flipped Classroom Learning Model Integration with Socio-scientific Issues

	Syntax	**Description**
Online	Initial observation.	The teacher greets and explains the learning process that will be applied. The teacher asks students to explore the material in the learning videos provided.
	Controversial issue orientation.	The teacher presents learning videos containing teaching materials and controversial issues. In their worksheets, students raise questions about the materials and SSI issues and determine solutions to them.
Offline	Feedback from learning videos.	Students discuss advanced learning materials and materials that have yet to be understood.
	Student organization.	Students are divided into groups. Each group contains 4-5 students.
	Arguments against existing controversial issues.	The teacher facilitates students in each group to discuss their notes about SSI issues from learning videos in their worksheets.
	Making decisions related to issues	Students present their previously built arguments with their group mates by conducting dialogue, discussion, and debate with other groups related to the issues.
	Conclusion.	Students are asked to conclude the results of problem-solving from the issues given.

2.4 Research instruments

The objects of the research were critical thinking skills and scientific attitude, collected before and after the learning process. The critical thinking skills test (CTST) and scientific attitude scale (SSA) were used to measure critical thinking skills and scientific attitudes, respectively.

Critical Thinking Skills Test (CTST)

A critical thinking skills test (CTST) was used to collect data on students' critical thinking about additives and addictive substances. The aspects of students' thinking skills have been synthesized from Ennis (1989), Facione (2015), and Watson-Glaser Critical Thinking Appraisal (WGCTA) (Grimard & Wagner, 1981). The aspects include the introduction of assumptions, providing a basic explanation, interpretation, analysis, evaluation, and summing up. First, the CTST consisted of 15 open-ended questions. Five experts carried out content validation by assessing the accuracy of the synthesis of aspects and indicators, the suitability of the questions and answer keys, and the use of grammar. Based on the expert's suggestions, the CTST was revised. For instance, using an introduction to the SSI issue in question and the latest issues, the empirical validation was piloted on 71 9th-grade students of one junior high school. The Rasch model was used to determine the quality of the item fit. The results showed that ten questions fit valid CTST questions from six aspects of critical thinking skills (see Table 2) for the reliability analysis of the questions using Cronbach's alpha value, namely the interaction between the person and the items as a whole contained in the results of the analysis of the Rasch model. The reliability results on the input Rasch model with a value of 0.77, so it can be concluded that the CTST was reliable.

Scientific Attitude Scale (SSA)

The scientific attitude scale (SSA) was used to collect scientific attitude data. The aspects of scientific attitude skills were synthesized from Fraser (1978), Irfandi et al. (2019), and Price & Lee (2013). The number of items in the SSA before the validation was 48. The results of the construct validation analysis were then analyzed using the Rasch model, resulting in 43 valid items to measure students' scientific attitudes. The reliability analysis using Cronbach's alpha on the input Rasch model was a value of 0.90, meaning that the SSA was reliable. The scientific attitude indicators are shown in Table 3.

Table 2. Indicators of critical thinking skills

No	Aspect	Indicator
1.	Introduction of assumptions	Identifying assumptions Assessment of assumptions
2.	Providing a basic explanation	Focusing on question Analyzing arguments
3.	Interpretation	Categorizing Clarifying the meaning
4.	Analysis	Testing ideas Identifying arguments Identifying reasons and questions
5.	Evaluation	Assessing the credibility of the question Assessing the quality of arguments made with inductive or deductive reasoning.
6.	Summing up	Deducing and considering deductions Inducing and considering the results of induction Creating and assessing the values of the results of consideration.

Table 3. Scientific Attitude Indicators

No	Aspect	Indicator
1.	Social implications of science.	The role of science in social life. Relation of social problems to science.
2.	Application of scientific attitude.	Persistence in completing tasks.
3.	Use of scientific knowledge to evaluate problems.	Use of scientific knowledge to solve problems. Use of scientific knowledge in arguments.
4.	Interest in working in the field of science.	Desire to pursue a career in science. Desire to become a scientist
5.	The convenience of learning science.	Comfort in learning science. Enthusiasm in learning science.
6.	Curious attitude.	Interest in observing objects or events that are strange, new, and interesting to him. Interest in information related to science.
7.	Open attitude.	Willingness to hear opinions. Interest in digging for information.
8.	Objective.	Decision making based on facts. Respect for facts.

3 Data analysis

Multivariate Analysis of Variance (MANOVA) was used to determine the significant effect of the FCM-SSI model on students' critical thinking skills and scientific attitudes. Three assumptions of the MANOVA test had been made before the MANOVA was performed (Stevens, 2002; Hair et al., 1998): normality test, general linear model test, and matrix-covariance similarity test. Then the post-hoc analyses were done to determine the aspects of critical thinking skills and scientific attitudes that influence intervention with FCM-SSI. In addition, ANOVA was used to see the differences between each aspect of CSTT and SSA.

4 Findings

4.1 The effect of the FCM-SSI model on critical thinking skills and scientific attitudes

The results of the MANOVA statistical analysis are presented below.

Table 4. Linearity Test Results for Critical Thinking Skills and Scientific Attitudes

	Critical Thinking Skills * Scientific Attitudes				
	Between Groups				
	(Combined)	*Linearity*	*Deviation from Linearity*	*Within Groups*	Total
Sum of Squares	1.363	.913	.450	.812	2.174
df	63	1	62	117	180
Mean Square	.022	.913	.007	.007	
F	3.119	131.644	1.046		
Sig.	.000	.000	.411		

The results of the linearity test, with a sig value of 0.411 > 0.05, indicate a linear relationship between critical thinking skills and students' scientific attitudes.

Table 5. Multivariate Test Results

Multivariate Test	Value	F	Sig.	Partial Eta Squared
Roy's largest root	.173	15.451b	0.000	.147

Based on Table 5, with a 95% confidence level, the value of sig. 0.000 ≤ 0.05 indicates a significant influence of the FCM-SSI learning model on students' critical thinking skills and scientific attitudes. The contribution of the FCM-SSI learning model to critical thinking skills and scientific attitudes is 14.7%.

The effect of the FCM-SSI learning model on each dependent variable is presented in Table 6 as follows.

Table 6. Univariate Test Results

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Critical Thinking	1135.350	1	1135.350	12.813	.001	.181
Scientific Attitude	442.817	1	442.817	15.699	.000	.213

The significance value is 0.001 ≤ 0.05 for the variables of critical thinking and scientific attitude 0.001 ≤ 0.05, indicating that the FCM-SSI learning model significantly affects critical thinking skills, and the FCM-SSI learning model also significantly affects scientific attitudes. The contribution of the FCM-SSI model to critical thinking skills is 18.1%, and to scientific perspectives is 21.3%.

4.2 The differences in critical thinking skills (CT) and scientific attitude in each aspect

Based on the analysis results using ANOVA for the results of critical thinking skills for each aspect in the experimental class, namely the value of sig. 0.001 ≤ 0.05, it can be concluded that there is a significant average difference between the six aspects of critical thinking skills, followed by the post-hoc test. The achievement of critical thinking skills results of the post-hoc test with Tukey after the intervention with FCM-SSI is presented in Table 7.

Table 7. Post-Hoc Results with Tukey for Critical Thinking Experimental Class

		Subset for alpha = 0.05			
Critical Thinking	N	1	2	3	4
Interpretation (C)	91	71.42			
Introduction of assumptions (A)	91		79.58		
Evaluation (E)	91		80.49		
Providing a basic explanation (B)	91			85.46	
Summing up (F)	91				93.47
Analysis (D)	91				96.37
Sig.		1.000	.994	1.000	.521

The highest average score is in the analysis aspect, with a value of 96.37. Each column in the data above (columns 1 to 4) shows a significant difference in each indicator. In column 2, there is an introduction of assumptions and evaluation data, meaning that the average value of the introduction of assumptions and evaluation is similar. Column 4 contains data on the summing up and analysis aspects, meaning that the average summing up and analysis values do not differ significantly.

The results of the post-hoc test analysis of critical thinking skills for each aspect in the control class are presented in Table 8.

Table 8. Post-Hoc Results with Tukey for Critical Thinking Control Class

Indikator CT	N	Subset for alpha = 0.05		
		1	2	3
Interpretation	91	65.35		
Evaluation	91	66.21		
Introduction of assumptions	91		75.57	
Providing a basic explanation	91		80.22	80.22
Summing up	91			82.59
Analysis	91			84.04
Sig.		.998	.211	.427

Post hoc results on indicators of critical thinking skills in the control class show the highest average score on the analysis aspect with a value of 84.04. In column 1 there is an interpretation and evaluation of the data. In column 2, there is a data introduction of assumptions and a basic explanation; in column 3, data provides an introductory explanation, summing up, and analysis. Each indicator contained in the same column has no significant difference.

The analysis of the scientific attitude of each aspect using ANOVA shows the value of sig. $0.000 \leq 0.05$ means a significant average difference in the eight elements of scientific attitude after the intervention using FCM-SSI. Because there is a difference in the average, it is continued with the post-hoc test. The post-hoc test results experimental class are presented in Table 9.

The post hoc test results showed the highest average value of the scientific attitude of the experimental class in the open attitude aspect, which was 94.68. In column 1, there is data on the aspect of interest in working in the field of science and using scientific knowledge to evaluate problems. In column 2, there is data on the convenience of learning science and the application of scientific attitude. In column 3, there is data on the application aspect of scientific attitude and curious attitude, and column 4 contains data on objective aspects, social implications of science, and open attitude. Each aspect included in the same column has no significant difference.

Table 9. Post-Hoc Results with Tukey for Scientific Attitude Experimental Class

Scientific Attitude	N	Subset for alpha = 0.05			
		1	2	3	4
Interest in working in the field of science (D)	91	73.40			
Use of scientific knowledge to evaluate problems (C)	91	73.81			
The convenience of learning science (E)	91		83.96		
Application of scientific attitude (B)	91		85.60	85.60	
Curious attitude (F)	91			88.62	
Objective (H)	91				93.67
Social implications of science (A)	91				93.71
Open attitude (G)	91				94.68
Sig.		1.000	.909	.282	.994

The post-hoc test results for the scientific attitude of the control class are presented in Table 10.

Table 10. Post-Hoc Results with Tukey for Scientific Attitude Control Class

		Subset for alpha = 0.05			
Indikator SI	N	1	2	3	4
Interest in working in the field of science	91	72.93			
Use of scientific knowledge to evaluate problems	91		76.92		
The convenience of learning science	91		80.13		
Social implications of science	91			84.97	
Objective	91			85.89	85.89
Open attitude	91			86.34	86.34
Curious attitude	91			86.74	86.74
Application of scientific attitude	91				89.27
Sig.		1.000	.174	.852	.127

Post hoc test results in the control class showed the highest scientific attitude value in applying scientific attitude, with a value of 89.27. In column 1, there is data on interest in working in the field of science. In column 2, there is data on the use of scientific knowledge to evaluate problems and the convenience of learning science, column

3 is data on aspects of Social implications of science, objective, open attitude, and curious attitude, and column 4 contains objective aspect data, open attitude, curious attitude and application of scientific attitude. Each aspect included in the same column has no significant difference.

5 Discussion

This study aimed to see the FCM-SSI model's effect on critical thinking skills and scientific attitudes in junior high school students and which aspects of critical thinking skills and scientific attitudes were most influential after the intervention using FCM-SSI. The following is a discussion of each research result.

5.1 The effect of the FCM-SSI model on critical thinking skills and scientific attitudes

The statistical analysis showed that the FCM-SSI model affected CT skills and students' scientific attitudes. The contribution of the FCM-SSI learning model to critical thinking skills and scientific attitudes is 14.7%. The effect of the FCM-SSI model on each variable shows that the FCM-SSI learning model has a significant impact on critical thinking skills and also a significant effect on scientific attitudes. The contribution of the FCM-SSI model to critical thinking skills is 18.1%, and to scientific attitudes is 21.3%. This study's results align with the research conducted by Kong (2014), which found that students had significant CT development in the intervention using the flipped classroom. In addition, other studies show that the flipped classroom model has created a deep learning environment, meaningful learning, and critical thinking development (Thi Lan Huong et al., 2018).

The FCM-SSI model collaborates with the flipped classroom model and socio-scientific issues to apply the characteristics of FCM and SSI in its implementation. The FCM-SSI model begins with an online intervention which is characteristic of FCM, namely an explanation of the material given to students in a video and watched before class, then continued at school with class time spent on active learning activities, problem-solving, evidence-based learning, group discussion, analysis, and synthesis. FCM allows students to benefit from studying at a flexible time, place, and pace by learning through learning videos and preparing for interactive classroom sessions. Class sessions are then used to synthesize concepts and solve problems given by the teacher (Chick et al., 2021). So this FCM requires student commitment, such as behavioral, cognitive, and affective commitment, both in pre-class and face-to-face activities.

In addition, research on SSI, such as that conducted by Solbes et al. (2018), proved that using SSI in the classroom facilitates the development of critical competencies. Therefore, promoting the pedagogical process with the SSI approach can strengthen the process of developing critical thinking. The nature of SSI is about giving issues, where these issues are open and related to morals and ethics that can cause conflict. Because the competition in SSI directs students to analyze, evaluate, and create solutions (Zeidler et al., 2009). Issues in the SSI context will provide many opportunities for students to exchange ideas with other teams and groups. Applying FCM-SSI in the classroom will make students more involved in sharing, evaluating, reflecting, and drawing conclusions about various arguments. Small group discussion cohesiveness also allows students to practice listening to team members (developing an attitude of openness and curiosity), evaluating and reflecting on peers' comments (forming reviewing assumptions, analyzing and objectively) and seeking consensus in their groups (i.e., providing explanations basis and conclusion). Through this activity, critical thinking skills and scientific attitudes will be formed. Because the scientific attitude of students is more dominant, it is only created from the characteristics that exist in SSI, so the contribution of the FCM-SSI model to scientific attitudes is less than that of CT skills.

Interventions with FCM-SSI use controversial issues as authentic tasks in real-world contexts. Authentic learning experiences involve real-world topics or problems and provide opportunities for students to communicate, collaborate, and reflect (Lowell & Moore, 2020). Through authentic learning, students can develop critical thinking and problem-solving skills by tackling structured problems (Jonassen, 2008). Unstructured problems, or problems with many possible answers, allow students to engage in critical thinking processes, such as looking for alternatives and considering other points of view (Kim et al., 2013). In the application of FCM-SSI, students think critically in solving controversial issues by applying science concepts to everyday life problems in small cooperative groups so that scientific attitudes will also be formed. In addition, this model also applies a pattern of collaborative learning, an interactive environment, the interaction between peers, and the existence of negotiations in the classroom environment. Cooperative and collaborative learning can improve critical thinking skills (Abrami et al., 2008) and scientific attitudes (Harun & Utiya, 2010).

In addition, the nature of the FCM-SSI includes scientific practices such as planning and conducting investigations. In this case, patterns can train CT skills and scientific attitudes both online and offline, as implied in the FCM-SSI syntax. In the online phase, in terms of orientation to controversial issues, from the learning videos provided, students make questions related to the material presented on SSI issues and try to create solutions to SSI issues, with this activity training students in growing CT skills in terms of asking essential questions of the material presented, making assumptions, as well as analyzing and interpreting the content of learning materials. In addition, they will also train their scientific attitude in terms of being curious about the material in the video and the SSI issues given, using their basic knowledge of science, and being comfortable learning science. In the offline phase, regarding arguing against controversial problems, making decisions related to issues, and drawing conclusions, students will practice CT skills in providing essential explanations, interpreting, analyzing, evaluating, and concluding. In addition, in training students' scientific attitudes, they will appear interested in working in science, openness, objectivity, and attitudes to using scientific knowledge in conducting discussions, dialogues, and debates.

The FCM-SSI model focuses on applying the material to controversial issues. In contrast, the traditional classroom focuses on learning, such as more examples of material application. Therefore, traditional students are told how the actual content of the material is through direct learning, while students in FCM-SSI conduct discussions, debates, and problem-solving through active learning. Active learning activities, problem-solving, evidence-based learning, group discussions, knowledge application, analysis, and synthesis, will improve critical thinking skills and scientific attitudes as research conducted by Tomesko et al. (2022), active learning, direct feedback, and increasing student involvement in the classroom can improve students' thinking skills. In addition, scientific attitudes characterized by curiosity and criticalness, logic, objectivity, honesty, and open-mindedness, according to Ali et al. (2013), are all included in the characteristics of the FCM-SSI model.

The main points that stood out during the intervention using the FCM-SSI model were: 1) The duration of lectures in online videos was short. This time duration is necessary to maintain student involvement; therefore, the content of the video only contains essential information or is based on learning objectives. 2) To avoid students who do not open videos at home, through a learning platform that is used by continuously providing motivation and support for students, both instructional support and technical support, so that they want to study the material at home and fill out the worksheets at home. So one of the benchmarks of whether students watch the material from home is by filling out their worksheets at home. 3) The controversial issue given was an issue that was trending at the time, thus making students more motivated to study the issue further. 4) The application of this model when used on students, especially junior high school students aged between 11 to 15 years with a developmental level at the stage of operation of the format, according to Piaget (1966), students at this level can perform logical operations wisely based on limited learning experience. Therefore, students still need guidance to argue by involving the components of SSI by providing provocation questions to direct them in the discussion.

5.2 Differences in critical thinking skills and scientific attitudes in each Aaspect

Based on the results of the ANOVA analysis, there are significant differences in the results of critical thinking skills in each aspect. Likewise, in scientific attitudes, there are significant differences in the results of scientific attitudes in every aspect. In thinking skills, the highest or the most influential is the analysis, and the lowest part is the interpretation. These results are by research conducted by Susanti et al. (2014) that students find it challenging to solve problems involving the use of HOTS, and among the difficulties they face are a) reading and interpreting data, b) determining and delegating data, and c) making conclusions and arguments. Regarding Bloom's taxonomy level, the highest indicator is at the C4 level, and the lowest is at the C5 level. The HOTS questions based on the revised Bloom's Taxonomy are questions of type C4 (analysis questions), C5 (evaluation questions), and C6 (making questions) (Anderson & Krathwohl, 2001), so that the questions most answered by students are the first level of HOTS.

The intervention of watching videos before class and SSI discussions provided many opportunities for students to analyze, discover, and examine the videos and SSI issues given. In addition, SSI discussions offer opportunities for students to make arguments, reflect on arguments from different perspectives, and interact with fellow learners. SSI problem argumentation activities require many other arguments require the ability to evaluate and provide opportunities for students to practice reflection (Lin et al., 2012). Analysis, evaluation, and creation are cognitive processes applied when learning at home and in the classroom. The FCM-SSI intervention helps students develop perceptions through several levels, such as at the cognitive level on

HOTS, from the information processing stage through videos to building knowledge through discussion activities on SSI issues in class. Thus, if this model is applied, critical thinking can be developed.

For students' scientific attitude, the most influential aspect is the aspect of open thinking, and the lowest is the aspect of interest in working in the field of science. The intervention with FCM-SSI uses more time in class to discuss solving a given controversial problem so that the open-thinking aspect will be trained and curiosity will also arise. Then by using FCM-SSI, which involves students in making decisions about SSI issues, so that with this SSI issue students will know how the role of science in social life and the relationship between social problems and science. The lowest aspect was interest in working in the field of science. Most junior high school students are still hesitant about working in the field of science. This is also to the results of research from (Gulacar et al., 2022), according to which students' interest in science education worldwide is worrying, and the interest of students who want to continue their science education is decreasing. The study also found that students with a high scientific attitude generally provide a more detailed, varied, and comprehensive view of SSI problems.

Meanwhile, students with low scientific attitudes reported more biased opinions. Therefore, the results of this study also show that students with high critical thinking skills also have high scientific attitudes. This result can be seen from the linearity test results showing a significant linear relationship between critical thinking skills and scientific attitude. Osman et al. (2003) state that students' critical thinking disposition reflects their scientific attitude.

6 Conclusion and implications

This research is an initial study using the FCM-SSI model by looking at students' critical thinking skills and scientific attitudes. The results showed that the FCM-SSI model significantly affected critical thinking skills and students' scientific attitudes. This study also indicates that the most influential aspect of students' thinking skills is the analytical aspect, and the lowest is the interpretation aspect. The aspect of scientific attitude with the most influence is openness and the lowest is the aspect of interest in working in science. The results of this study indicate that the FCM-SSI model is recommended to be used in science learning, especially in junior high schools, because of its potential to improve student's critical thinking skills and scientific attitudes.

Based on the results of this study, the researcher recommends promoting critical thinking skills and scientific attitudes with more emphasis on these developments, including exploring videos, making arguments, making conclusions, and making decisions based on the characteristics of the FCM-SSI. In addition to this intervention, there is also a need for support for students, especially from teachers, because this learning involves technology and independent learning, mainly if applied to junior high school students. The researcher also recommends further research to see students' self-efficacy or self-regulation using the FCM-SSI model.

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CRITICAL THINKING SKILLS TEST INSTRUMENT

Aspect	Questions
Introduction of assumptions	1. TEMPO.CO, Jakarta - The West Jakarta Police Narcotics Unit arrested two suspected drug dealers of methamphetamine and ecstasy types at a luxury apartment in Cawang, East Jakarta. Apart from arresting a pair of men and women, namely ANC, 31 years old, and DAA, 36, the police also confiscated evidence of a suitcase containing methamphetamine and ecstasy. "Our members managed to arrest two perpetrators suspected of being drug dealers," said West Jakarta Police Chief Kombes Police Audie S Latuheru in Jakarta, Monday, October 5, 2020. West Jakarta Police Head of Narcotics Unit Kompol Ronaldo Maradona Siregar said the arrest was an extension of the case for the arrest of three suspects and 2.5 kilograms of methamphetamine in an area in Cipinang. However, Ronaldo has not been able to provide more detailed information regarding the chronology and details of the results of the arrest of the drug dealer. "We are still carrying out a more intensive investigation, and we will reveal it at a press conference in the near future," he said. Why should the person distributing the drugs be arrested? What are the disadvantages of drug use so that the authorities must secure traffickers? 2. Watch the case below! Suara.com - Abuse of narcotics or drugs is starting in teenagers and students. Based on BNN data for 2018, drug abuse at this age increased by 3.2 percent, or the equivalent of 2.29 million people. The former BNN Rehabilitation Deputy Dr. dr Diah Setia Utami reveals at the Drug Abuse and its Impact on HR Quality, Monday (7/6/2021) drugs can affect a person's behavior. He said drug users tend to take risky actions, even killing others. And not only that but drugs can also change a person's behavior to be inappropriate, which can affect his sexual life. Worst of all, drug users can end up in confusion and memory loss. "This should be a concern for all of us for future generations. How will the resources be if Indonesia's drug market continues to grow?" he asked sadly. However, can someone who is addicted to drugs be cured? According to Dr. Diah, drug users are not entirely fixed but can recover from their habit. Based on this case, explain at least three efforts made by the next generation to avoid drug or narcotic abuse!
Application of scientific attitude	1.  Schoolchildren usually buy snacks during breaks or after school. Of the many types of snacks often sold in schools, some of the most popular snacks among children are shown in the picture below. In your opinion, do these snacks contain additives? Explain why you are suspicious! 2. Culinary practitioners often use both synthetic and natural dyes to beautify their dishes. Natural dyes made from plants, animals, and minerals are safe for consumption, but color choices are limited. Synthetic dyes are an option. What are the advantages of synthetic dyes so that many people choose them? Describe one example of using dyes that are not by their designation and the impact on health!
Interpretation	1. An instant powder drink packaging includes the following composition. 1) granulated sugar 5) tricalcium phosphate anti-champ 2) Orange flavor 6) Aspartame sweetener 3) Tamarind 7) Coloring tartazine Cl 19140

<table>
<tr><td></td><td>
4) Antioxidant TBHQ
Based on the composition, determine natural and artificial additives!
Do you think this product is safe for consumption? Give your reasons!

2. TRIBUN-BALI.COM, DENPASAR - When he became a drug addict, Wayan Agus Arta admitted being very tormented. The physical and mental conditions are disrupted due to addiction to these prohibited drugs. This resident from Batubulan, Gianyar, told about an incident that happened to him. One night, around 23.00 WITA, Wayan Agus Arta Mudita's body suddenly shook. Cold sweat slowly leaked from the pores of his skin. His body was hot. Gradually, all parts of Agus's body vibrated, giving off excruciating pain. For about two hours, he endured the pain while occasionally screaming. "At that time, I didn't know what was wrong with my body," this former heavyweight drug addict told the Bali Tribune last week. "After my friend came and was told that I was withdrawn. Previously, I did consume heroin four days in a row. On the fifth day, my money ran out. I didn't wear it, and the pain arose," he said.
a. Based on the issues above, why will sufferers experience withdrawal if they don't consume psychotropics? Why on drugs hurt? And what is the impact on drug sufferers?
b. Psychotropics can cause specific changes in mental activity and behavior to cause addiction in the wearer. Explain the effects of psychotropics on the body so that they can have an impact like that!
</td></tr>
<tr><td>Analysis</td><td>

Getuk lindri is a traditional Javanese cake in traditional markets and city cake shops. Getuk lindri is a market snack made from the main ingredient of cassava, added sugar to add sweetness, and some coloring. Based on the picture of getuk lindri on the side, four dyes are used: yellow, green, brown, and red. Explain the natural dyes used to produce the four colors of the four colors!
</td></tr>
<tr><td>Evaluation</td><td>
Look at the content table for several types of food products below!
<table>
<tr><th>Types of food products</th><th colspan="4">Additive content</th></tr>
<tr><td>K</td><td>Saccharin</td><td>Guinea green B</td><td>Sulfur dioxide</td><td>Oil yellow OB</td></tr>
<tr><td>L</td><td>Sodium benzoate</td><td>Orange GGN</td><td>Palm sugar</td><td>Cyclamate</td></tr>
<tr><td>M</td><td>Papain enzyme</td><td>Ebi</td><td>Orange GGN</td><td>Grape</td></tr>
<tr><td>N</td><td>Pandan leaves</td><td>Beet sugar</td><td>Sodium benzoate</td><td>Chicken broth</td></tr>
<tr><td>O</td><td>Sodium benzoate</td><td>MSG</td><td>Suji leave</td><td>Oil yellow AB</td></tr>
</table>
Based on the table above, answer the following questions.
a. Determine 1 type of food product that is most unfit for consumption! Explain your answer!
b. Determine 1 type of food product that is most suitable for consumption! Explain your answer!
</td></tr>
</table>

	c. For the least suitable food, provide alternative ingredients that you think are safe for consumption!
Summing up	A food coloring test was conducted on food products sold on the roadside. Based on the results of laboratory tests, several types of products contain dyes that are not permitted, namely textile dyes. a. In your opinion: What is the feasibility of the product as a food ingredient? b. What solutions can be taken by students, POM agencies, and the police to prevent the misuse of materials like this?

Scientific Attitude Instrument

Aspect	Statement
Social implications of science.	1. I feel science is often encountered in everyday life. 2. Science cannot help explain some of the social phenomena that I experience/see. 3. I often do activities related to science. 4. Science is only a theoretical lesson in school and has nothing to do with natural events. 5. I am happy to encounter social phenomena related to science learning in schools.
Application of scientific attitude.	1. I always complete school assignments on my own. 2. I feel responsible for the tasks that I have done myself. 3. I often see a friend's work to complete my task. 4. I was always relaxed about doing schoolwork and often looked at friends' work to complete it. 5. I always complete school assignments by seeking answers from various sources and making sure the answers are appropriate/correct. 6. I rarely complete all the school assignments to the best of my ability.
Use of scientific knowledge to evaluate problems.	1. I do not consider the risk (profit/loss) before doing activities or encountering problems. 2. I always use a theoretical or experiential learning approach to solve problems/problems. 3. I always prepare mentally and materially before speaking and expressing opinions in learning. 4. I always argue as I see fit without considering it first.
Interest in working in the field of science.	1. I am interested in studying science in depth. 2. I don't want to work in science. 3. I will love science so that later I will be involved in science. 4. I want to be something other than a researcher in science. 5. I am interested in something other than researching and learning more about science. 6. I aspire to become a scientist in science, such as a doctor, physicist, chemist, etc.
The convenience of learning science.	1. I always feel happy when studying science. 2. Studying science is very dull for me. 3. Studying science could be better for me. 4. I always get new questions and have great curiosity when studying science. 5. Learning science does not increase my enthusiasm for learning.

Curious attitude.	1. I am not interested in observing social phenomena related to science. 2. I enjoy being involved in solving problems about social phenomena related to science. 3. Social phenomena related to science are a challenge for me. 4. I want to look for something other than science-related information from various sources. 5. I never look for science information apart from learning at school. 6. The information provided in science lessons at school is minimal, so I look for other sources as additional information.
Open attitude.	1. Discussions and listening to opinions from friends and teachers about science can add new information. 2. I do not allow my friends to give their opinion when discussing. 3. I feel bored and don't focus on listening to people's opinions in group discussions. 4. I always feel curious about the information received from various sources. 5. Whenever new information is received, I look for a more detailed explanation.
Objective.	1. I do not refer to existing facts. 2. I make conclusions based on the results of the discussion. 3. I did not double-check the correctness of the arguments presented by my classmates. 4. I will change my opinion if it does not fit existing theories or facts. 5. I am closed to consider other people's opinions. 6. I recheck the things I have investigated regarding the problem given.