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Jurnal Inovasi Pendidikan IPA, 9 (1), 2023, 84-94

Utilizing social media in socioscientific issues discussion to improve argumentative skills and microbial literacy

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Received: 20 January 2023; Revised: 3 March 2023; Accepted: 3 March 2023

Abstrak: Microbial literacy plays an essential role in understanding microbiology issues. Discussion of socioscientific issues is one way to improve microbial literacy and argumentative skills. Socioscientific issues discussion takes a long time if applied in an inadequate classroom. Thus, social media is used as a tool to discuss socioscientific issues. This study aims to utilize social media Facebook' in discussing socioscientific issues. The research method used is quasi-experimental. The pre-post one group design was used to know the effect of socioscientific discussion on argumentation skills, and the pre and post-control group design was used to know the differences in microbiological literacy of students who discuss socioscientific issues and did not discuss socioscientific issues. Discussion of socioscientific issues is carried out through four steps: polemic, exploration, conclusion, and action. The results showed increased individual argumentation skills before and after discussing socioscientific issues via Facebook. Before the discussion there are 34.38% of students reached argumentation levels 4 to 5, after which 56.25% reached argumentation levels 4-5. Discussion of socioscientific issues through social media has made group argumentation skills reach higher performance (level 5). Microbiological literacy between groups discussing socioscientific issues and not discussing socioscientific issues showed no significant difference except for questions directly related to the topic of discussion, namely changes in perceptions of microbes. Online discussions of socioscientific issues with pro and con arguments were very effective through social media "Facebook."
***Keywords**: argumentation skill, microbial literacy, socioscientific issues*

How to Cite: Herlanti, Y., Rustaman, N. & Rohman, I. (2023). Utilizing social media in socioscientific issues discussion to improve argumentative skills and microbial literacy. *Jurnal Inovasi Pendidikan IPA, 9*(1), 84-94. doi:http://dx.doi.org/10.21831/jipi.v8i1.57910

INTRODUCTION

Microbial-related issues have generated public fear in some instances, for example, the cases of microbial diseases, such as Chicken Pox (the 1970s), HIV-AIDS (1990), Avian and Swine Flu (2000s), and COVID-19 (2020). Another example is microbial contamination of food. Recent food contamination issues by *E. sakazakii* and *E. coli* have also received wide attention in Indonesia. The issues have created a negative view of microbes. Most people became afraid of all microbes. Microbes not only cause diseases, but some microbes are also beneficial for humans and the environment. Bacteria help us do a fantastic array of valuable things, such as producing vitamins, breaking down some types of garbage, and maintaining our atmosphere. Protista is part of the microbial food chain and makes up a significant fraction of its biomass. Fungi greatly help us, from bread processing to waste decomposing and recycling.

The microbe-related fear was merely a result of a lack of knowledge of microbes or a lack of microbial literacy. Literacy enables individuals to use scientific processes and principles in making personal decisions and participate in discussions on issues that affect the social environment, and make decisions on these issues (Dani, 2011). Microbiology literacy is knowledge of relevant microbial activities, how they impact our lives, and how they may be harnessed for the benefit of humankind. Microbiology literacy in the general population and the subsets constituting the decision makers (Timmis et al., 2019).

In scientific literacy, microbial literacy is defined as connecting microbiology content and process and microbiology content with context (Nuangchalerm, 2010). Discussion of socioscientific issues was

http://dx.doi.org/10.21831/jipi.v8i1.57910

one way to connect content to context. Socioscientific issues tend to create controversy as they are influenced by cultural and sociopolitical issues (Dawson & Venville, 2009). Socioscientific issues may occur due to science and social interconnection (Chang & Chiu, 2008). In other words, socioscientific issues may involve social and scientific components. (Gott & Duggan, 2007)

Discussion of socioscientific issues explores the nature of science (Nuangchalerm, 2009, 2010), which helps improve science literacy (Dawson & Venville, 2009; Erduran et al., 2005; Marrero & Mensah, 2010; Nuangchalerm, 2010). In the discussion, the debate consists of scientific knowledge, ethics, and values (Erduran et al., 2005). Therefore, this forum would improve the student's ability to provide arguments (Chang & Chiu, 2008; Dawson & Venville, 2009; Erduran et al., 2005), analytical thinking (Wongsri & Nuangchalerm, 2010), and moral reasoning (Sadler & Zeidler, 2004; Wongsri & Nuangchalerm, 2010) and informal reasoning (Chang & Chiu, 2008; Dawson & Venville, 2009). The success of socioscientific issues discussion depends on the readiness of students and teachers. Students need sufficient knowledge of cross-disciplinary science (Dani, 2011). Meanwhile, the teachers should master the issues and be able to manage and assess the discussion of the socioscientific issues (Reis, 2009)

Several international previous studies showed that the discussion on socioscientific issues has increased argumentative skills (Erduran et al., 2005; Albe, 2007; Chang & Chiu, 2008; Dawson & Venville, 2009; Parween Anwar & Abid Ali, 2020). The increase in argumentative skill occurs because, during the discussion process, participants develop, consider, and dispute their arguments, which results in the span of discussion (Erduran et al., 2005; McNeill, 2009). Discussion on socioscientific issues needs a pure topic, i.e., an issue that can be explored from several points of view, not only from a scientific point of view but also from politics, values, ethics, economy, society, and cultures. There are some microbiology issues developed in Indonesia. Based on a previous study, Contamination by E. *sakazakii*, the issue in Indonesia had been socioscientific.

The issue started when IPB University found E. *sakazakii* in infant formula and food. This finding influenced how researchers viewed the physiology of E. *sakazakii* and its impacts on the political economy and academic ethics. From the physiology point of view, *E. sakazakii* is an opportunistic pathogen (1) that dies at a temperature over 70°C (7). From social, economic, and political points of view, people plead for transparency of the infant formula brands that E. sakazakii allegedly contaminated. However, IPB refused to reveal its findings publicly because of ethical reasons as well as academic ethics. The controversy happened in 2008-2011, which was relatively recent and thus deemed an interesting discussion topic.

Discussion of socioscientific issues entitled "Debate concerning *E. sakazakii"* might have been done in a classroom in a limited time allocation. Alternatively, the discussion had been taking place in the virtual world by using social media. Online Social networking, "Facebook," is a potential tool due to the large number of users in Indonesia, 49.715.620 users (http://socialbakers.com). On Facebook, a user can create a discussion group. Group discussions can be set to private so that the participants feel assured and can enjoy the discussion. In the discussion group, a user (moderator) writes a post to make a motion, and then participants write comments to respond to the motion or refute another participant's comments. Users can use tags such as (@) to express support or rebuttal of the arguments raised by other participants and hashtag (#) to show the primary claims. This study was designed to discuss socioscientific issues in microbiology on the online social networking site, "Facebook." The objective is to improve students' microbial literacy and argumentative skills. The research questions were as follows: Can socioscientific issues discussion improve microbiology literacy? Can socioscientific issues discussion improve argumentative skills?

METHOD

Pre- and post-test one-group design was used to analyze the improvement in argumentative skills. The research design of argumentative skills can be seen in Figure 1.

Pre-Discussion		Post-Discussion	Participants
O	X	O	35 students

Figure 1. Pre-Post One Group Design

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Pre- and post-test control group design was used to analyze the effect of socioscientific issues (SSI) on microbial literacy. A control group is a group of students who discuss but do not use socioscientific issues (NON-SSI). The research design of microbial literacy can be seen in Figure 2.

Participants	Pre-Lecturing		Pre-Discussion		Post-Discussion
31 Students	O1	X	O2	X	O3
30 Students	O1	-	O2	-	O3

Figure 2. Pre and Post Control Group Design

The data collected consists of arguments and scores of microbial literacy tests. Students produced arguments directly during the discussion and wrote the arguments on paper prior to and after the discussion. They also participated in microbial tests before the lecturing, before, and after the discussion.

The microbial literacy test was adapted from Needham (1999). Microbial literacy instruments were translated into Indonesian and went through linguistic validation (Sperber, 2004). A few questions were added for the context of Indonesia, which two microbiology experts then validated. In addition, 107 prospective West Java teachers participated in field validation. The microbiology literacy instrument consists of 30 questions with a reliability of 0.64 and a correlational of 0.47.

There are two kinds of argumentative skills data, i.e., (1) arguments before and after the discussion process and (2) arguments during the discussion. The assessment rubric for the arguments before and after the discussion process was adapted from Dawson & Venville (2009); Erduran et al. (2005). The rubric can be seen in Table 1. Meanwhile, the rubric for the arguments during the discussion process was adapted from Erduran et al. (2005). The rubric of the argument is in Table 2.

Table 1. Arguments Assessment For Argumentation Pape

Level	Explanation
1	Only wrote claim
2	Wrote claims, data, and warrant
3	Wrote claim, data, warrant, backing, or qualifier
4	Wrote claim, data, warrant, and qualifier.

Table 2. Arguments Assessment in a discussion of socioscientific issues through Social Medi

Level	**Explanation**
0	No comment
1	Give comments as claims but not related to the previous comments.
2	Give comments as a claim related to the previous comments to support or refute the prior claims with a new claim.
3	Give comments related to the previous comments to support or refute the prior claims with a new claim and data.
4	Give comments related to the previous comments to support or refute the prior claims with a new claim, data, and warrant.
5	Give comments related to the previous comments to support or refute the prior claims with a new claim, data, support, warrant, and qualifier.

Descriptive and inferential statistics analyzed the microbial literacy test data. Three tests were given as follows: before the lecture, after six sessions of lecturing or prior to the socioscientific issues discussion, and after the discussion. N-Gain (Meltzer, 2002) and Tpair test were used to analyze the improvement in microbial literacy. The Effectiveness of the Socioscientific Issue Discussion was analyzed using the Mann-Whitney U test.

RESULT AND DISCUSSION

Argumentative skills on socioscientific issues discussion

Based on the previous study, Facebook has been used as socioscientific issues discussion tool. Facebook has several strengths regarding privacy options, comment capacity, active participation

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

facility, speed, and accessibility. Socioscientific issues discussion does utilize not only Facebook but also weblog. The design of the socioscientific issues discussion can be seen in Figure 3.

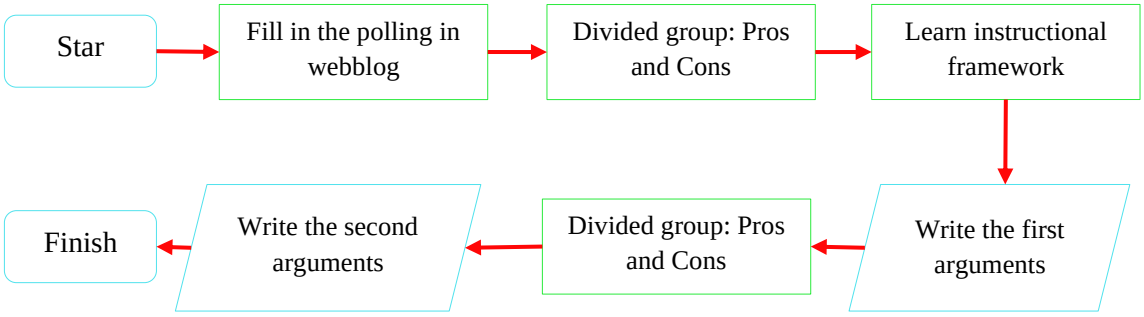

Figure 3. The design of socioscientific issues discussion in media social.

Before the discussion, students filled in the polling provided in the weblog. Next, students were divided into pro and contra groups based on the polling. After that, students learned the instructional frameworks and rules of the discussion. The weblog used in this learning can be accessed at http://educationalmicrobiology.wordpress.com. Discussion on Facebook involved 42 students. There were about 2,024 comments for all sessions of discussion.

In the first session, students discussed the E. *sakazakii* polemic, in which they would agree or disagree with the motion proposed by the moderator. The motion was "Should IPB reveal the brands of milk and infant food that E. sakazakii contaminates?" There were 705 comments for this session. Participants were divided into two groups of pros and cons. There were 23 participants on the pros side of "no revelation of the milk and food brands that contaminated by *E. sakazakii*" and 19 participants in the cons group, "revelation of the brands that contaminated by *E. sakazakii."*

The second session discussed the exploration of *E. sakazakii*, including metabolism, physiology, and habitat. The motion was, "What do you know about E. *sakazakii*, and should we get alarmed?" There were 647 comments for this motion. The third session discussed social action. Participants had to think about the promotion of microbial literacy. The motion was "What would you do to prevent the public's dismay caused by a microbe (*E. sakazakii*)?*"* There were 625 comments for this motion. They shared many ideas and began to plan the promotion of microbial literacy for Secondary School and non-Biology majors in higher education, also for women and men who prepare formula and food for their babies. The fourth session gave the state of the art. Every participant gave a conclusion. They might rethink their opinion. There were 47 conclusions in this session.

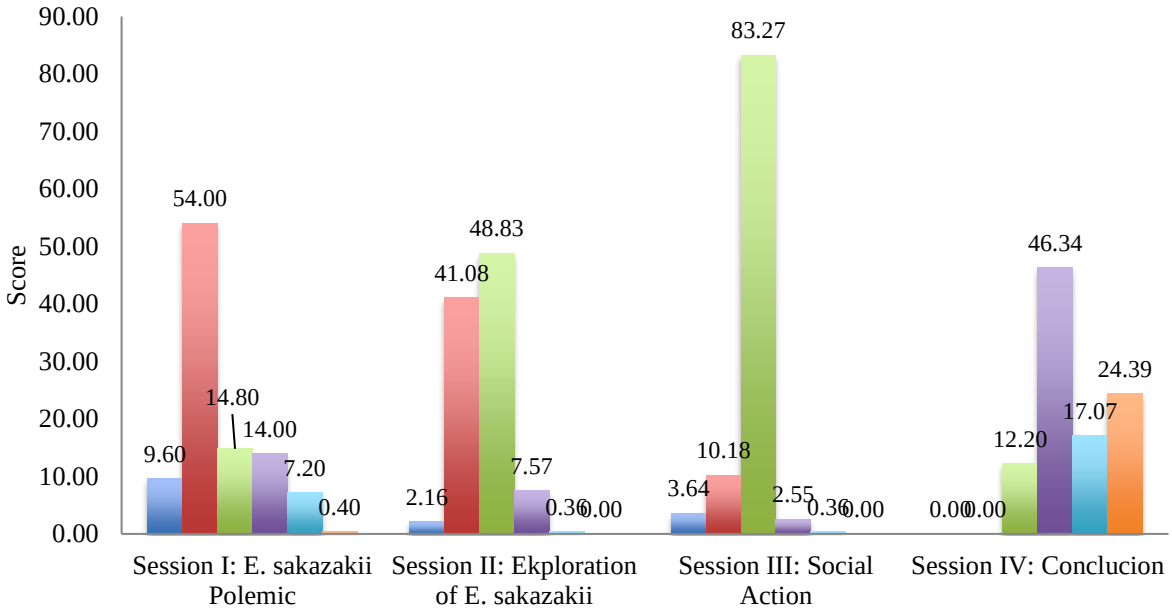

Figure 4. Quality of Arguments During Discussion Process

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

In the first and third sessions, participants' arguments were based on their social, economic, and cultural values and science, especially socioscientific values. It is contrary to the second session of discussion, which required a scientific view. Individually, the quality of participants' arguments varied, ranging from level 0 to 5. Most participants obtained levels 1 and 2 by providing a claim and claim supported with sufficient data. Figure 4 shows the qualities of arguments during the socioscientific issues discussion. An example of arguments during socioscientific issues discussion is shown in Table 3.

Table 3. Example Arguments During Discussion of Socioscientific Issue

Level	Explanation	Example
0	No comment	*EL* What is the reason for MA to approve the publishing of contaminated infant formula brands?
1	Give comments as claims but not related to the previous comments.	*WP* I also agree that BPOM should conduct socialization at the clinic, but no need to reveal the infant formula brand.
2	Give comments as a claim related to the previous comments to support or refute the prior claims with a new claim.	*CL* Responding to @NBK's statement, BPOM does not inform or provide a solution on the internet, but BPOM should broadcast on the TV; it is the public right.
3	Give comments related to the previous comments to support or refute the prior claims with a new claim and data	*FA* agreed @AN, @EL IPB does not reveal the brand of the milk being used as samples in their research because there are international codes of research that protect the brand products as the research objects. Also, National Education System protected academic freedom in Article 24 of Law No. 20 Year 2003.
4	Give comments related to the previous comments to support or refute the prior claims with a new claim, data, and warrant.	BLA, Agreed @LS, IPB wanted to research only, not to survey, see on http://www.kopertis12.or.id/2011/02/17/terkait-penelitian-ipb-tentang-bakteri-susu-enterobacter-sakazakii.html. 2. There is a code of ethics research.http://www.mediaindonesia.com/read/2011/03/02/207130/68/11/Etika-Penelitian-vs-Kepentingan-Publik. 3. The announcement could impact the welfare of the manufacturer's workers. Moreover, they are lower class. 3. It Already exists to handle, so why still worried? http://www.republika.co.id/berita/gaya-hidup/info-sehat/11/02/19/164956-begini-cara-memusnahkan-enterobacter-sakazakii-dalam-susu-formula
5	Give comments related to the previous comments to support or refute the prior claims with a new claim, data, backing, warrant, and qualifier.	*NS* Add and support the comment of @NA; until now, no news about babies infected by E. Sakazakii. Yes, there was news about *E. sakazakii* that infected premature babies. However, we know premature babies are very susceptible to anything. Not only because of the bacteria *Enterobacter Sakazakii*. *Enterobacter Sakazakiiis* is dangerous, but it causes nothing if we know how to handle it (http://www.tribunnews.com/2011/02/21/ahli-mikrobiologi-enterobacter-sakazakii-tidak-berbahaya) Prof. Dr. Sam Suharto Sp.MK Chairman of PAMKI confirmed that Enterobacter Sakazakii in formula milk is not harmful to humans.

As a group based on a map of arguments, the students have gotten the 5th level of argumentation. The students' arguments showed breadth with many rebuttals. Figure 5 shows the map of students' arguments in media social groups, especially in the polemic session, "Should IPB reveal the brands of milk and infant food that E. sakazakii contaminates?". The map of argument showed the completeness and complexity of arguments. In groups, each student contributed by giving claims, warrants, backings, and rebuttals. Able's research (2007) also showed that argumentation processes within students' group

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discussions made students elaborate on scientific data, general ideas, and epistemological and strategic considerations.

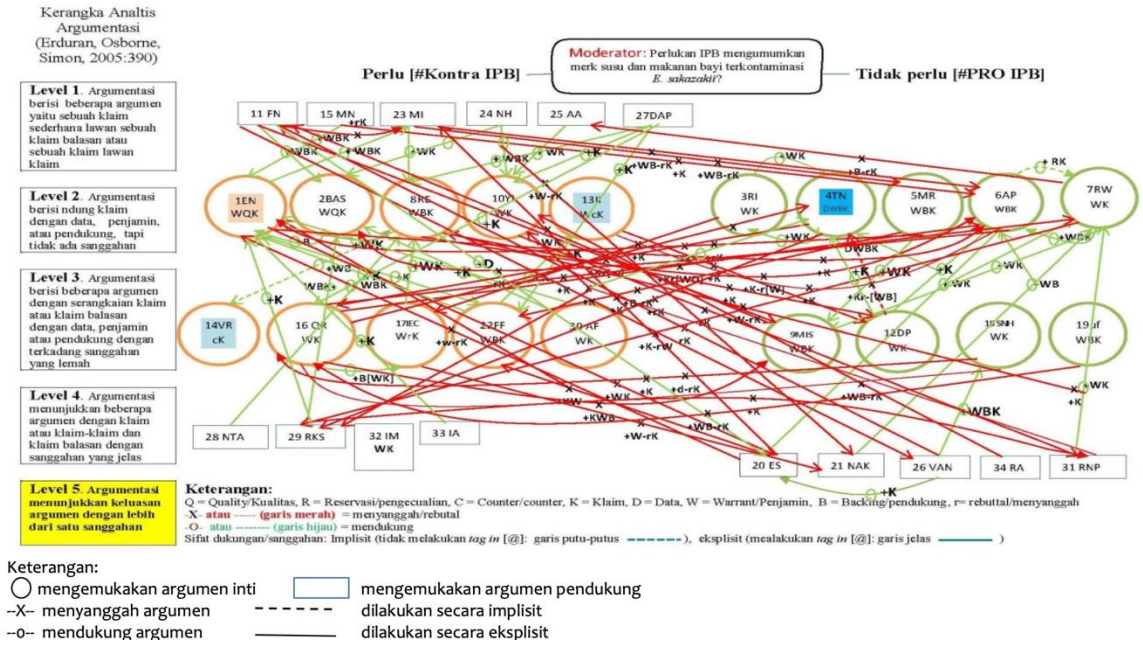

Figure 5. Map of Arguments of all students in the Media Social Group

Increasing argumentative skills

From the arguments' papers, we observed an improvement in the quality of the argument. The result is displayed in Figure 6. The quality of arguments after discussion increased ($\mu \pm SD$, $3.59 \pm 1.10 > 3.03 \pm 0.82$) and showed a difference significantly (t=3.999; Sig 2-tailed= 0.000). Figure 5 shows that the student's level of argumentation skills increased after online SSI discussion. Improving students' argumentation skills after discussing socioscientific issues online confirms previous findings that SSI can promote argumentation skills and the effectiveness of argumentation in online discussions (Tsai, 2018).

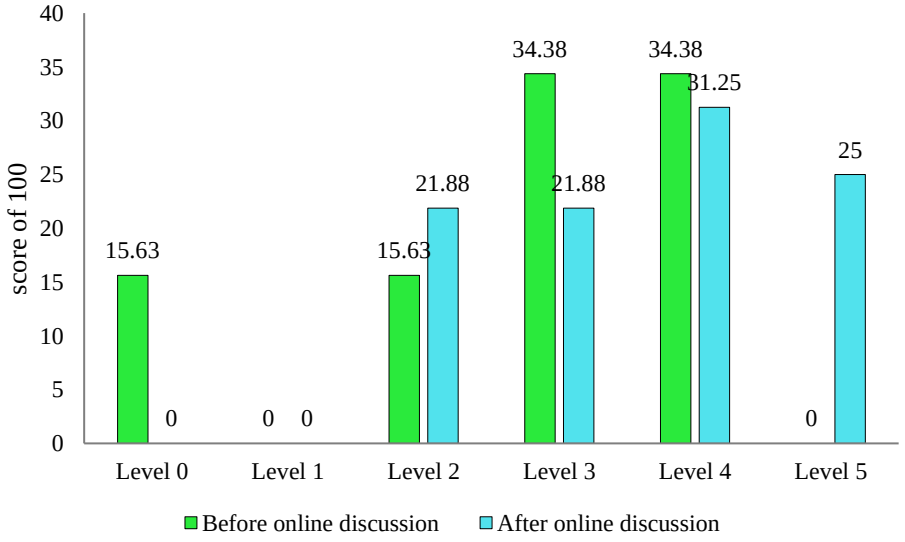

Figure 6. The quality of Arguments before and after discussion of the socioscientific issue

Microbial Literacy

Discussion on socioscientific issues slightly improves microbiology literacy, and such improvement is classified as low (see Table 4). Generally, microbiology literacy improvement before and after lecturing does not show significant results. A similar result occurs before and after discussing

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

socioscientific issues (see Table 5). It shows microbiology literacy is permanent and has no significant changes after lecturing and discussing socioscientific issues.

Table 4. Average, Standard Deviation, and N-Gain of Microbial Literacy

Parameters	SSI Group		
	Pre Lecturing	Pre Discussion	Post Discussion
Average	71,51	72,8	75,16
SD	10,42	9,60	8,07
N-Gain	004		0,08

Table 5. Tpair Test Microbial Literacy for SSI Group

		N	Correlation	Sig.	t	df	Sig. (2-tailed)
Pair 1	Pre-Lecturing – Pre Discussion	31	.675	.000	-1.262	30	.217
Pair 2	Post-Discussion – Pre Discussion	31	.652	.000	.832	30	.412

Microbial literacy for every item of the test can be seen in Figure 6. This figure shows lower microbial literacy on numbers 6, 12, 15, 16, 17, 20, 21, and 25. This result is similar to Rowe's research (Rowe, 2010)). Most students failed to understand that most microbes were not quickly grown in a laboratory and that most human genes were related to microbial genes. There were some misconceptions in some specific areas. The textbook must be revised, and specific efforts must address the misconceptions.

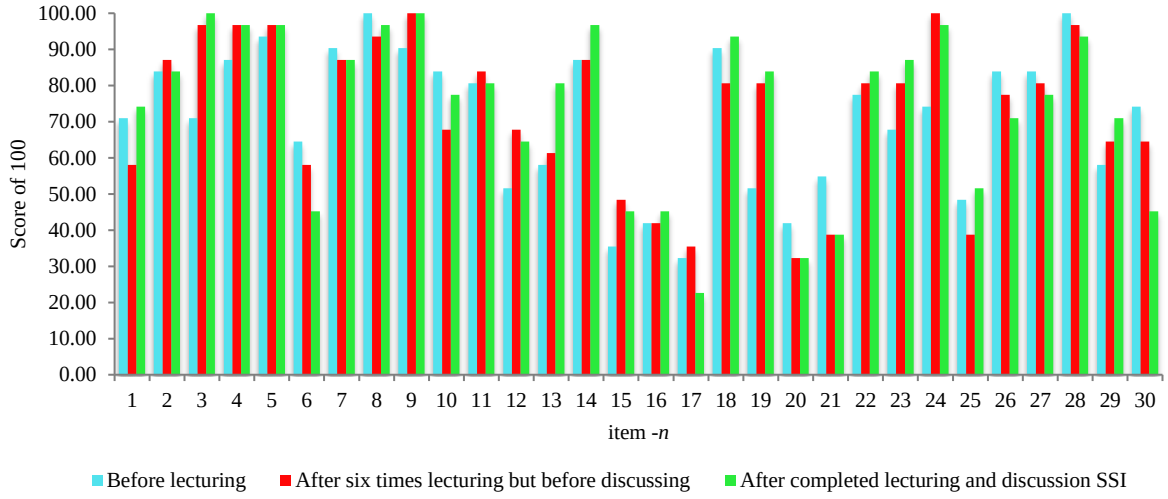

Figure 6. Microbial literacy before lecturing, after six times lecturing but before discussion of SSI, after completing lecturing and discussion SSI

Discourse analysis during discussion of socioscientific issues showed 16.7% of questions of microbial literacy (number 1, 3, 4, 7, and 22) related to content discussion SSI. The number of comments for five microbiology literacy questions can be seen in Table 6.

Table 6. Result from Discourse Analysis: Comments in Issue Socioscientific Discussion Relevant to Some of Microbial Literacy Questions

No	Microbial Literacy Questions	Number of Comments
1 4.	Most microbes cause diseases in plants and animals. Microbes play significant roles in making all life possible on the planet.	**39** (Keywords: literate, perception, mind)
3.	There is more microbial diversity than other living things.	**6** (Keywords: taxonomy)
7.	Antibiotics can kill almost all kinds of viruses.	**42** (Keywords: antibiotics)
22.	Microbes cannot reproduce and die at temperatures of 0 to 7°C	**241** (Keywords: temperature)

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

The questions related to the discussion topic are analyzed further to determine the effectiveness of socioscientific issue discussion. The average score of the questions can be seen in Table 7, which shows that the improvement of microbiology literacy results in the SSI group is higher than in the Non-SSI group (See Table 7). However, the Mann-Whitney U test results show insignificant differences in both groups, whether prior to and after the lecturing or before and after the discussion (see Table 8 through 10).

Table 7. Average, Standard Deviation, and N-Gain of Microbial Literacy

	SSI Group			NON SSI Group		
	Pre Lecturing	**Pre Discussion**	**Post Discussion**	**Pre Lecturing**	**Pre Discussion**	**Post Discussion**
Average	79.35	83.87	88.39	74.67	78.00	82.00
SD	16.72	15.85	13.44	22.24	17.68	13.24
N-Gain	0.27	0.21		0.16	0.13	

Note: SSI = Discussion used Socioscientific Issue; NonSSI = Discussion used non-socioscientific issue

Table 8. Mann Whitney U Result for Microbial Literacy Before Lecturing

	Groups	**N**	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney U**	**Z**	***p***
Pre Lecturing	1 (Non-SSI)	30	28.83	865.00			.344
	2 (SSI)	31	33.10	1026.00	400.000	-.947	

Table 9. Mann Whitney U Result for Microbial Literacy After Six Sessions of Lecturing and Before Discussion Session

	Groups	**N**	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney U**	**Z**	***p***
Pre Discussion	1 (Non-SSI)	30	28.22	846.50			
	2 (SSI)	31	33.69	1044.50	381.500	-1.216	.224

Table 10. Mann Whitney U Result for Microbial Literacy After Discussion Session

	Groups	**N**	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney U**	**Z**	***p***
Post Discussion	1 (Non-SSI)	30	29.45	883.50			
	2 (SSI)	31	32.50	1007.50	418.500	-.676	.499

It is fascinating to see number one. Question number 1 is related to participants' perceptions of microbes. Most participants positively perceive that "A large percentage of microbes do not cause diseases in plants and animals." Some other participants' perceptions change because of the lecturing and discussion. Table 11 displays a negative perception that "A large percentage of microbes cause diseases in plants and animals" lasts longer in the NonSSI group than in the SSI group. It shows that there are more changes of perception about microbes happening in the SSI group, from negative perceptions to positive ones. The results of the t-test display that the changes in participants' perceptions happened owing to the discussion of socioscientific issues (see Table 12).

Table 11. Microbial literacy for number one: Perception Change

Group	**Negative Perception**					**Positive Perception**					**Total**
	0-0-0	**0-1-0**	**1-1-0**	**1-0-0**	**Sum**	**1-1-1**	**0-1-1**	**0-0-1**	**1-0-1**	**Sum**	
SSI	2	1	4	1	8	13	3	3	4	22	31
Non SSI	10	2	3	0	15	11	0	1	3	15	30
Sum	12	3	7	1	23	24	3	4	7	27	61

Note: SSI = Socio-scientific Issue Discussion; Non-SSI = Discussion of non-socio-scientific issue; x1 – x2 –x3 = pre-lecturing, pre-discussing, post discussing; 0= wrong perception; 1= right perception

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Table 12. T-Test Microbial Literacy for Number One

	Groups	N	Mean	Std. Dev	Equality F	Equality Sig.	t	df	*p*
Pre Lecturing	1 (Non-SSI)	30	.57	.50	4.481	0.039			
	2 (SSI)	31	.71	.46			1.157	59	.252
	Total	61							
Post 6 sesion Lecturing/Pre discussion	1 (Non SSI)	30	.43	.50	.047	.830			
	2 (SSI)	31	.58	.50			1.144	59	.257
	Total	61							
Post Discussion	1 (Non SSI)	30	.50	.50	8.871	.004			
	2 (SSI)	31	.74	.44			1.980	59	.052
	Total	61							

Tables 11 and 12 showed microbiology literacy for specific questions related to discussing socioscientific issues and showed significant differences compared to the group that did not discuss socioscientific issues (Non-SSI). SSI's effect on scientific literacy has also been found in recent research. Permanasari's research (Permanasari et al., 2021) showed that SSI increased scientific literacy in the knowledge aspect, but the improvement is still low in the attitude aspect. The meta-analysis of the SSI effect on science learning also showed that SSI had a significant effect on junior high school (1.43) and senior high school (0.96) and a medium impact on college (0.55) (Badeo & Duque, 2022).

CONCLUSION

Social media "Facebook" is an alternative social media that can effectively support online discussions of socioscientific issues. Discussions through social media made students more active so that the quality of group arguments could reach level 5. The quality of individual arguments significantly increases after discussing socioscientific issues online. Microbiology literacy for specific questions about discussing social-science issues also showed significant differences compared to the group that did not discuss socioscientific issues (Non-SSI). After the Covid19 pandemic, blended learning has been developed in universities and schools. Online discussion of socioscientific issues can be an alternative online learning method to improve argumentation skills. Online discussion of socioscientific issues conducted through social media provides several advantages. For example, in a controversial status, 700 people can comment without disturbing the low loading. However, existing social media is only designed to provide comments, yet it cannot automatically assess the quality of words written. Future research can develop online socioscientific issue discussion media integrated with argumentation skills assessment, making it easier for teachers to collect, process, and assess the quality of argumentation written by students in the comment column. Future research is also expected to develop discussions of socioscientific issues in courses that contain controversial science issues such as evolutionary theory, Genetically Modified Organism (GMO) consumption, pros and cons of vaccines, and pros and cons of bays reclamation in Indonesia. In addition, courses with literacy targets such as ecology (eco-literacy) can utilize the discussion of socioscientific issues to strengthen the link between ecological concepts and the context of problems occurring in the ecosystem.

REFERENCES

Albe, V. (2007). Students' Argumentation in Group Discussions on a Socioscientific Issue. In *Contributions from Science Education Research*. Springer Netherlands. https://doi.org/10.1007/978-1-4020-5032-9_30

Badeo, J. M., & Duque, D. A. (2022). The effect of Socioscientific Issues (SSI) in teaching science: A meta-analysis study. *Journal of Technology and Science Education, **12***(2), 291. https://doi.org/10.3926/jotse.1340

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Chang, S., & Chiu, M. (2008). Lakatos' Scientific Research Programmes as a Framework for Analysing Informal Argumentation about Socioscientific Issues. *International Journal of Science Education, **30***(13), 1753–1773. https://doi.org/10.1080/09500690701534582

Dani, D. (2011). Sustainability as a Framework for Analyzing Socioscientific Issues. *International Electronic Journal of Environmental Education, **1***(2). www.iejeegreen.com

Dawson, V., & Venville, G. J. (2009). High-school Students' Informal Reasoning and Argumentation about Biotechnology: An indicator of scientific literacy? *International Journal of Science Education, **31***(11), 1421–1445. https://doi.org/10.1080/09500690801992870

Erduran, S., Osborne, J., & Simon, S. (2005). The Role of Argumentation in Developing Scientific Literacy. In *Research and the Quality of Science Education*. https://doi.org/10.1007/1-4020-3673-6_30

Gott, R., & Duggan, S. (2007). A framework for practical work in science and scientific literacy through argumentation. *Research in Science & Technological Education, **25***(3), 271–291. https://doi.org/10.1080/02635140701535000

Marrero, M. E., & Mensah, F. M. M. (2010). Socioscientific Decision Making and the Ocean: A Case Study of 7 th Grade Life Science Students. *Electronic Journal of Science Education **14***(1). http://ejse.southwestern.edu

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education, **93***(2), 233–268. https://doi.org/10.1002/sce.20294

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American Journal of Physics, **70***(12), 1259–1268. https://doi.org/10.1119/1.1514215

Needham, C. (1999). The view from America's back porch. *ASM News, **65***(4), 215–219.

Nuangchalerm, P. (2009). Development of Socioscientific Issues-Based Teaching for Preservice Science Teachers. *Journal of Social Sciences, **5***(3), 239–243.

Nuangchalerm, P. (2010). Engaging Students to Perceive Nature of Science Through Socioscientific Issues-Based Instruction. *European Journal of Social Sciences **13***(1).

Anwar, N. P., & Ali, M. A. (2020). The effect of socioscientific Issue (SSI) based discussion: A student-centred approach to the teaching of argumentation. *Scholarship of Teaching and Learning in the South, **4***(2), 35-62.

Permanasari, A., Sariningrum, A., Rubini, B., & Ardianto, D. (2021). Improving Students' Scientific Literacy Through Science Learning with Socio Scientific Issues (SSI). In *5th Asian Education Symposium 2020 (AES 2020)* (pp. 323-327). Atlantis Press.

Reis, P. (2009). Teaching Controversial Socioscientific Issues in Biology and Geology Classes: A Case Study. *Electronic Journal of Science Education Volume, **13***.

Rowe, G. (2010). Assessment of a Novel General Biology Course for Improving Microbial Literacy of Non-Science Majors in a Liberal Arts College . *17th Annual ASM Conference for Undergraduate Educators*. https://doi.org/10.1128/jmbe.v11.i1.155

Sadler, T. D., & Zeidler, D. L. (2004). The morality of socioscientific issues: Construal and resolution of genetic engineering dilemmas. *Science Education, **88***(1), 4–27. https://doi.org/10.1002/sce.10101

Sperber, A. D. (2004). Translation and validation of study instruments for cross-cultural research. *Gastroenterology, **126***, S124–S128. https://doi.org/10.1053/j.gastro.2003.10.016

Timmis, K., Cavicchioli, R., Garcia, J. L., Nogales, B., Chavarría, M., Stein, L., ... & Harper, L. (2019). The urgent need for microbiology literacy in society. *Environmental microbiology, **21***(5), 1513-1528.

Tsai, C.-Y. (2018). The effect of online argumentation of socioscientific issues on students' scientific competencies and sustainability attitudes. *Computers & Education, **116***, 14–27. https://doi.org/10.1016/j.compedu.2017.08.009

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Wongsri, P., & Nuangchalerm, P. (2010). Learning outcomes between Socioscientific Issues-Based Learning and Conventional Learning Activities. *Journal of Social Sciences, **6***(2), 240–243. http://ir.library.oregonstate.edu/jspui/bitstream/19

ISSN 2406-9205 (print), ISSN 2477-4820 (online)