

## The scientific argumentative skill analysis reviewed from the science literacy aspect of pre-service teacher

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### ABSTRACT

Scientific argumentative skills could encourage the critical thinking skill of college students about scientific phenomena. This research aimed to measure and describe the scientific argumentative skill of the primary school teacher candidates, reviewed from the scientific literacy. This research applied the quantitative method by using a survey typed cross-sectional design. The researchers selected the participants with convenience sampling. The results were 184 college students of even semester of 2020/2021. The applied instrument was the validity process. The data collecting techniques were test and questionnaire assisted with a Google Form. The test instrument consisted of four items. Then, the questionnaire item of the student's perceptions about the argumentative scientific skills consisted of ten items. The researchers arranged the instruments with the indicators of science literacy-based scientific argumentative skills about biodiversity. The validity results showed that the test and questionnaire instruments were valid, relevant, and reliable to measure the skills. The researchers measured the argumentative scientific skills with Toulmin argumentative pattern (TAP) that was modified. The scientific argumentative skill profiles of the students showed that a percentage of 52% students was at level 3. However, there were no students reaching level 5. The students' perceptions showed that they were interested in expressing their arguments and confidence while expressing their opinions. The results suggested the science educators prepare teacher candidates with argumentative scientific skills by developing learning innovation. The empowerment strategy by using scientific argumentation measurement is essential to apply to create better primary school teacher candidate with 4.0 century skills.

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## 1. INTRODUCTION

The teacher candidates should have mastered the 4.0 era skill, especially at the primary school level. The education process of teacher candidates is essential to prepare them as future agents. They will have jobs to prepare the next generations. The education quality should be improved continuously. It includes at the university level [1]. Various challenges to support the skills should be the priority for a higher education institution. The required skills are such as critical, creative, problem-solving, and argumentative skills. Albab

and Anisyah [2] found that argumentative skills had essential learning processes, significantly higher education institutions for all educational levels. The argumentative scientific skills allow students to develop their higher conceptual understanding. Probosari *et al.* [3] found that some educators were not optimal to establish their scientific argument ultimately.

Scientific argumentative skills are the process to enhance the claim by emphasizing the skills to express ideas, information, and opinion based on the existing theory and evidence. Osborne [4] found that argumentation was a validating or rebutting activity by reflecting scientific evidence and values. In line with previous study that discovered arguing could be considered verbal, social, and rational activities to enhance the logical critics about an argument [5]. The Organization for Economic Co-operation and Development (OECD) [6] found a similar thing: the cognitive-linguistic skill acknowledged as the essential component for literate citizens in this 21st century. Argumentation is the cognitive-linguistic skill with a critical role in 21st century thought [7]–[9]. Rahmadhani *et al.* [10] argued that scientific argument was essential to develop because it trained to think scientifically, communicate, and act like scientists. Argumentative skill development has an essential role in science learning activities. These argumentative scientific skills allow students to participate and express their arguments that represent their conceptual knowledge.

Scientific argumentation has an essential role in science learning. Science learning is identical to scientific works, attitudes, and process skills. This skill allows students to elicit relevant information, evidence, and verification of the information and the arguments. Besides that, various argumentative skill developments enable students to express their explanations based on the synthetic result with science literacy thinking patterns. Teaching scientific argumentation could explain several complex phenomena clearly [11]. By involving them in arguing, students will learn to respect the correlation between evidence and claim. They also understand the importance of revision in scientific arguments. The argumentation quality has been developed in theoretical [12] and methodological frameworks for the conception [13] and scientific argumentation analysis [14]–[16].

Moreover, it could deepen or develop students' conceptual understanding [11], [17]. However, based on the previous study, the argumentative scientific skills of students were low [18]. Only two students provided argumentation with data, evidence, and rationale, while about a percentage of 30% of students only argued without supportive data or evidence. The data of Sudarmo *et al.* [19] also revealed that most of the students were not skillful in writing a scientific argument. They did not understand and could not connect the information with the explanation about phenomena or conceptions. Teacher candidates need to improve their knowledge, skill, and reliability to improve their argumentative scientific skills. Wardani *et al.* [20] suggested students should be involved in scientific discussion. Even, they should be the decision-makers of related scientific problems to face future challenges. Every individual must determine the choice or decision based on scientific information. It is to handle daily life problems and produce a useful scientific product and comes from science literacy. Science literacy is one of the science education targets [21]. Norris and Phillips [22] found that one educational objective is to create a literate community scientifically.

The students' argumentative skills will develop maximally based on the development of their science literacy knowledge. Xiaomei and Erduran [23] argue that argumentation is an essential component in scientific literacy. Thus, by adequately claiming, students could at least master scientific concepts. The data of the research showed that the science literacy of students was at the nominal level. It showed that students could understand the thinking pattern. They had not maximally understood the problems and applied the problem-solving practices. The instrument used to measure the literacy measurement was the multiple-choice model by sharing the students' reasons. From the measurement, the obtained data were in the form of reasons in answering the questions. Thus, they could be generalized and used to show the argumentative science skills of the student that were low. It proved the students' skills were still limited on re-writing the data and writing the claim.

On the other hand, scientific argumentation requires warranty, backup, and rebuttal. It showed that some students were only guessing to answer or provide the reasons. Thus, their motives were not based on the argumentative science components. Thus, it could be confirmed that the students' scientific argumentative skills were limited in determining problem patterns. Therefore, it required an appropriate instrument to assess the skill distributions of the Primary School Teacher Education program students of Universitas Muria Kudus, in Central Java, Indonesia. The scientific argumentation measurement pattern was based on Toulmin argumentation pattern (TAP). This model's scientific argumentation components are data, claim, warrant, backing, and rebuttal. Data deals with the applied phenomena as evidence to support a claim. The claim consisted of the results of the used scores, the arguments about specific situation values, and the emphasis of the perceptions. A warrant is regulation and principle that explains the correlation between data and claims. Support or backing is the basic assumption underlying a particular warrant. The rebuttal is a specific case where the claim cannot be verified or has different arguments [24].

On the other hand, Xiaomei and Erduran [23] argued that argumentation is essential in scientific literacy. Thus, by adequately claiming, students could at least master scientific concepts. It was strengthened by Ginanjar and Utari [25] who found that scientific argumentation referred to skills to express ideas or notions about any observed science phenomena based on data, evidence, or existing theories. Students who were aware of the uncertainty level would participate in higher-level arguments, use the warrant, promote scientific justification, and connect the evidence [26]. Students must train this skill to explain science phenomena based on the evidence and relevant science concepts. Argumentation becomes the principle to strengthen the claims of the thinking skills. The critical, creative, and problem-solving thinking analysis with supporting facts and accurate data could provide evidence and strong reasons. In addition, scientific argumentation skills can equip students to explain scientific phenomena that occur in everyday life based on theories based on scientific literacy. Measurement of student argumentation profiles is fundamental so that educators can develop appropriate learning. In addition, to prepare students who can make scientific arguments based on scientific literacy, it is essential to know the profile of students' scientific argumentation abilities. This study aims to measure and describe the scientific argumentation ability of elementary school teacher candidates from the aspect of scientific literacy and to determine the improvement of the quality of human resources, especially primary school teacher education students as primary school teacher candidates.

## 2. RESEARCH METHOD

This research applied the survey typed cross-sectional design. Creswell and Poth [27] argue that survey typed cross-sectional design is a procedure of quantitative analysis to collect the data within a specific time, but it is not regularly. The research population consisted of all even semester students in the 2020/2021 academic year. The sample was taken with convenience sampling. It was based on the consideration that students had joined the conceptual science course. There were 184 students of primary school teacher candidates. The data collecting techniques were test and questionnaire assisted with a google form. The test instrument consisted of four items. Then, the questionnaire item of the student's perceptions about the argumentative scientific skills consisted of 10 items. The researchers arranged the instruments with the indicators of science literacy-based scientific argumentative skills about biodiversity. The science literacy scopes were science contextual and science competence aspects. The scoring rubrics of argumentative scientific skills could be seen in TAP components. They consisted of: i) Claim - a skill to provide an answer with relevant data; ii) Warrant or evidence - a skill to rebuttal and provide the rational explanation based on scientific data to support the claim; iii) Reasoning - a skill to provide support with the rational explanation that connects the data with the claim; iv) Backing - a skill to share the supportive theory that is relevant with the reasoning or to create rebuttal based on the problems. The data analysis reference of the test was based on the modified TAP as shown in Table 1.

The developed instruments were validated and estimated in terms of reliability. The researchers validated the content and constructed it for both the test and questionnaire. The content validation was done by giving both instruments to the experts. They were science subject experts. The content validity fulfilment results were proved using the Lawshe concept [28], [29]. The (1) is written as:

$$CVR = \frac{2ne}{n} - 1 \quad (1)$$

Where, ne=the numbers of subject matter experts (SME) that assessed an essential item; n=the numbers of SME that promoted the assessment.

Lawshe [28] stated that the CVR value had an interval from -1 until 1. If half of the SME were essential, then the CVR value would be 0. CVR would be one if all SMEs were essentials for an item. On the other hand, the validity test value could be determined entirely with content validity index (CVI). The determination of CVI [28], [29] was done with (2).

$$CVI = \frac{(\sum CVR)}{k} \quad (2)$$

Where, CVR=Content validity ratio for each item; K=the question item numbers.

Table 1. The scientific argumentative skill scoring system

Claim	Warrant	Evidence/Reasoning	Backing/Rebuttal	Scores
The answers resemble the accurate and appropriate claim.	The answers cover all specific data presented in the problems.	The answers cover all connections of the evidence and claims.	The complex arguments were with more than one rebuttal.	5
The answers resemble the arguments with accurate claims.	The answers cover all specific data presented in the problems.	The answers cover all connections of the evidence and claims.	The answers resemble appropriate reasoning with the theory, but they are not accurate.	4
The answers averagely resemble the arguments with accurate claims.	The answers cover all specific data presented in the problems.	The answers partially cover all connections of the evidence and claims.	The answers resemble appropriate reasoning with the theory, but they are not accurate.	3
The answers cover arguments and all connections of the evidence and claims.	The answers partially resemble specific data presented in the problems.	The answers partially cover all connections of the evidence and claims.	The answers resemble appropriate reasoning with the theory, but they are not accurate.	2
The answers were simple arguments in the form of accurate claims.	The students could create a general statement with unspecific data.	The students repeated and reconnected the claim, but the results did not cover the scientific correlations.	The students could reason, but they did not refer to the existing theories.	1
Incorrect answers	The students did not mention the data or only provided inappropriate or incorrect data.	The students did not provide reasons, or they only shared wrong reasons.	The students could not share their reasoning results.	0

Source: the modified result of [2], [4], [13], [30]

The empirical validity was continued after the content validity had been done. It was obtained from the response analysis toward the test or questionnaire given for the respondents. The empirical validity could be determined with the use of classical test theory (CTT) or item response theory (IRT) [31], [32]. The data were analyzed with the Rasch model. According to Ibnu *et al.* [33], the Rasch model could solve the validity problem. The Rash model could provide statistics and investigate the test instrument validity based on the research subject responses. Rasch model developed the data measurement model to determine the correlation between the students' skills (personability) and the item difficulty with the algorithm function. It was to create a measurement with an equal-interval score [34]. Then, this research estimated the instrument reliability by using the alpha coefficient. The alpha reliability has the interval from 0 until 1. Streiner [35] argued that an instrument of preliminary research is reliable when the alpha probability score is 0.7. It is different from basic research. It will be reliable when the alpha score is 0.8. For medical purposes, the alpha probability of 0.95 is categorized as reliable. The scientific argumentative skill profiles based on the science literacy of the student were analyzed with the argumentative skill level criteria as shown in Table 2. The results were then calculated in terms of percentages.

Table 2. The criteria of argument quality

Criteria	Remarks
Level 5	Complex arguments with more than one rebuttal
Level 4	Arguments with the straightforward identified claims and rebuttals
Level 3	Arguments with <i>claims</i> or <i>counterclaims</i> that are completed with data, <i>warrant</i> , <i>backing</i> , and poor rebuttals
Level 2	The arguments consisted of claims with data, <i>warrant</i> , <i>backing</i> , and rebuttal
Level 1	Simple arguments with claim and counterclaim

Source: modified by [4], [30]

### 3. RESULTS AND DISCUSSION

#### 3.1. Content validity

There were 12 experts validated the test instruments. The results were used to determine the CVR index based on Lawshe [28]. It is: i) When the respondents that agreed or exceptionally agreed with the option were less than a half, the CVR value is (-); ii) When the respondents agreed or exceptionally agreed with the option were half of the total respondents, the CVR value is 0; iii) When all respondents agreed or exceptionally agreed with the option, the CVR value is 1. It was adjusted to 0.99 by considering the numbers of the respondents. The respondents of the research were twelve persons. Thus, the CVR critical value is 0.667; and iv) When the respondents agreed or exceptionally agreed with the option were half of the total respondents, the CVR value is -0.99.

After obtaining the CVR values, the CVI value was counted to describe the overall instrument item validity whether they had excellent contents or not. The validity results of the questionnaire obtained the CVR value 0.98 and CVI value 0.99. The CVR and CVI score calculation, based on the experts, met the minimum threshold, 0.667. Thus, the test and questionnaire instruments were valid, relevant, and reliable to measure.

### 3.2. Empirical validity and estimated reliability

The valid test instruments were given for the respondents, consisting of 184 students. The students' responses were analyzed with the IRT Rasch model. The analysis results can be seen in the Table 3. The counted results in Table 3 show the outfit mean squared value (MNSQ) is 0.99 for both person and item columns. The score, 0.99, is categorized fit. It is between the medium criterion,  $0.5 < \text{MNSQ} < \text{ZSTD} < 2.0$ . Thus, the data had a reasonable value probability. It means all question items or the items were in line with the Rasch model. Therefore, they could be used to measure the skill under the topic of biodiversity. The question item distributions were deemed fit based on the given requirement: if one or two items' elements were fulfilled. The first one, the MNSQ Outfit value, is between 0.5 until 1.5. The ZSTD outfit value is between -2.0 until 2.0. Then, the total score (point measure correlation) is between 0.4 and 0.85 [28]. Then, the researchers analyzed the students' responses from the questionnaire about their perception of science argumentative skills. The students' responses were analyzed with the IRT Rasch model. The analysis results can be seen in the Table 4.

The results show some difficult and easy question items to measure. However, in general, based on the test of expected score ICC, there were no irrelevant responses toward the question items. The item test (column): fit order in Winstep was used to determine the instrument item validity of the science argumentative skill perceptions with some decision-making criteria. The question items were valid if the OUTFIT MNSQ was between  $0.5 < \text{MNSQ} < 1.5$  (Table 4). Thus, all question items were between  $0.5 < \text{MNSQ} < 1.5$ . Thus, ten instrument items met the OUTFIT MNSQ criteria. It meant the items were fit and accurate to measure and were used in this research (Table 4).

Table 3. Statistic summary of the science argumentative skill measurement test instrument

	Remarks	Values
Logit	Person	0.00
	Item	0.00
Reliability	Person reliability	0.73
	Item reliability	0.99
	Alpha Cronbach	0.72
Outfit MNSQ	Person	0.99
	Item	0.99
Outfit ZSTD	Person	-0.16
	Item	-0.1

Table 4. Statistic summary of the questionnaire instrument about students' science argumentative skills

	Remarks	Values
Logit	Person	-0.25
	Item	0.00
Reliability	Person reliability	0.44
	Item reliability	0.99
	Alpha Cronbach	0.57
Outfit MNSQ	Person	0.99
	Item	0.99
Outfit ZSTD	Person	-0.24
	Item	-0.08

### 3.3. The profile of the science argumentative skill based on the primary school student department science literacy

The profile was made with the prepared instrument was fit or accurate to use. The argumentative science skills based on students' science literacy could measure the students' conceptual understanding of the biodiversity topic. Argumentative science skills could facilitate students to understand the science concept [36], [37]. It allowed students to develop and understand the idea they understood during the science learning process [11], [36], [38], [39]. Kaniawati and Suhandi [36] improve their science literacy and facilitate students to make a decision and solve problems [40], [41]. Fakhriyah and Masfuah [42] found that the argumentative process allowed students to develop scientific knowledge from the data, evidence, and

understanding of the scientific phenomena. While expressing their arguments with reasons, it meant students referred to the justification, claim, and scientific statement supports. The supports to the claim were argued with supports and rebuttals. The results of calculations using the Winstsep application is shown in Figure 1.

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ ZSTD	OUTFIT MNSQ ZSTD	PTMEASUR-AL CORR. EXP.	EXACT MATCH OBS% EXP%	Item
3	368	184	2.58	.12	1.31 2.87	1.34 3.18	.23 .49	58.5 55.9	Pe3
2	458	184	1.42	.11	1.16 1.53	1.17 1.68	.33 .48	52.5 53.8	Pe2
1	489	184	1.03	.11	1.33 3.02	1.35 3.23	.33 .48	53.6 54.1	Pe1
9	538	184	.41	.11	.96 -.35	.99 -.12	.40 .47	57.9 55.2	Pe9
8	557	184	.15	.12	.83 -1.77	.84 -1.73	.45 .46	65.0 56.1	Pe8
4	594	184	-.36	.12	.93 -.73	.89 -1.11	.61 .44	61.2 56.0	Pe4
10	600	184	-.45	.12	.74 -2.92	.75 -2.74	.54 .44	68.9 56.8	Pe10
6	655	184	-1.37	.14	.96 -.33	.84 -1.40	.60 .39	73.2 63.7	Pe6
7	655	184	-1.37	.14	.88 -1.18	.90 -.89	.51 .39	71.0 63.7	Pe7
5	684	184	-2.03	.16	.92 -.60	.86 -.94	.51 .35	78.1 74.6	Pe5
MEAN	559.8	184.0	.00	.13	1.00 .0	.99 -.1		64.0 59.0	
P.SD	94.3	.0	1.35	.02	.19 1.8	.21 2.0		8.2 6.2	

Figure 1. Item test result (column): Fit order

Eskin and Bekiroglu [43] found that students' science argumentative skills were essential to be applied during the learning activity. It had the function of triggering conceptual learning. Besides that, better conceptual understanding allowed students to provide complete science argumentation [44]. Furthermore, Argumentative skills with perceptions were essential to creating an explanation, model, and theory of a studied concept [12]. The data of the students' works based on the instrument were calculated in terms of the percentage according to Table 2. The data were analyzed descriptively with TAP. The argumentative science components were claim, evidence, warrant, backing, qualifier, and rebuttal [45].

The most significant percentage of the measurement showed 52% of students were at level 3. It meant the students had the skills with claims or counterclaims completed by data, warrant, backing, and rebuttal scientifically. There were 35% of students at level 2. It meant the students had argued with claims completed by data, warranty, and backing without rebuttal. On the other hand, no students reached level-5 science argumentative skills based on literacy based on the measurement. It meant their skills to argue in a complex manner had not included the mastery of providing complete data. It suggested educators revise the teaching method. Thus, the skills could be developed until they could give complex arguments with exclusive data or rebuttal. This argument in line with Erduran, Ozdem, and Park [46], they found that argumentative science skills in science education were essential. Thus, it had to be taught and studied in science class as part of investigation or literacy. The statement supported the explanation that the science argument was not based on sufficient conceptual knowledge. It was expected that the discussions would be helpful for students in understanding the materials [43]. The measurement results and the profile distribution of the students' skills can be seen in Figure 2.

The figure shows that the profile distribution of the measurement results is 5% students with level 4. It shows that the students started to develop, but they were less capable of expressing the arguments with clear identified claims and rebuttals. An excellent argument should be based on sufficient conceptual knowledge [47], [48]. Good conceptual understanding skills could support the other expertise in expressing the opinions. Fischer *et al.* [49] found that both deductive and inductive hypothetic methods could be used to create supporting evidence for arguments. The argumentative science skills were influenced by conceptual understanding that could be accepted by students entirely. Thus, there would not be any misconception or missing conception [42].

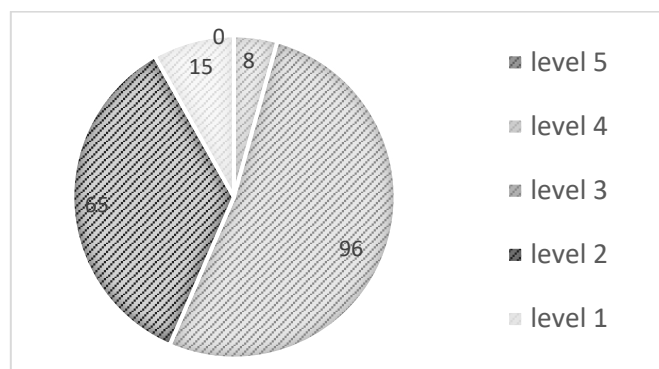


Figure 2. The profile distribution of science argumentative skills

### 3.4. The students' perceptions concerning the argumentative science skills

The measurement instruments used for the questionnaire were to determine and describe the students' perceptions toward the argumentative science skills. The score selections were (4=Extremely agree with the statement, 3=Agree with the statement, 2=Disagree with the statement, and 1=Significantly disagree with the statement). The measurement results can be seen in Figure 3. The results of item 1 show 86 students answered they agreed if one of the weaknesses was public speaking. It showed that most students had no self-confidence when they spoke in front of the public. Concerning the difficulty of speaking in front of the public, the second item showed 85 students did not feel so. Therefore, between the first and second items, they were supporting each other. It meant the students needed support to speak up and have confidence while speaking in front of the public. It was also seen in item 3. There were 112 students disagreed with the statement. They did not feel enjoy sharing opinions in a discussion forum. It showed that students did not feel enjoy when they were asked to share opinions.

Based on the fourth item, about the capability to argue if the students were brave, 72 students exceptionally agreed. Thus, they were very enthusiastic if they obtained opportunities to share scientific arguments. In item 7, 111 students agreed with the statements: the importance of argumentation skills and making students understand the materials and feel confident to express an opinion. The brave students to share their thoughts indirectly improved their intellectuality [50], [51]. In line with Albab and Anisyah [2], when the students argued, they needed a very prepared concept. Erduran and Jimenez [52] found that the other five dimensions would also be improved during science learning by developing argumentation. They were such as i) Cognitive and metacognitive process based on the performance characteristics of experts as a role model for students; ii) Critical thinking and communicative competence development; iii) Science literacy achievement, learners' bravery improvement to share an opinion and write an argument in scientific language; iv) Scientific, cultural pattern habituation and epistemic criterion development in knowledge clarification; and v) Scientific reasoning development, especially in choosing the compatible theories and scientific attitude determination based on rationality criteria.

Figure 3 shows that the fifth item obtains the highest score (4). It is with the question about the importance of training the argumentative skill through habituation. 138 students selected the score four out of 184 students. In item 6, 116 students answered highly agreed with the statement about the training of argumentative skills for all courses. In line with Kuhn *et al.* [53], they found that argumentative skills could not be obtained easily without training. The students required opportunities to express their scientific argumentation. Therefore, some strategies had to apply. It was in line with Ortega *et al.* [54] they found that preparing teacher candidates with reliable argumentative skills could be done with three strategies. They were i) Identifying the main elements in the science classroom argumentative skill process; ii) Interpreting the elements and creating habituation for science classrooms; and iii) Making a decision based on exercises for a better argumentative process.

The students' responses from those eight items showed 113 students agreed and were interested in sharing comments and arguments. It was in line with the student's scientific argumentative profile. It showed they were at level 3, with a percentage of 52%. However, this percentage also showed the skills to provide reasons or supporting data for the claim. It was categorized low. Previous researchers [55], [56] found that sharing reasons and data should be supported with concepts or theories the students studied previously. One hundred two students felt the confidence to rebuttal any inaccurate arguments (item 9). The responses from the statement were contradictory with the profile measurement result that showed the students had reached level 5. A group that showed students could argue, provide data, and rebut entirely and accurately. The tenth item showed that 106 students argued they needed evidence to show while sharing and defending their

arguments. The students' awareness to bring proof was observable. However, it was not entailed with proper conceptual understanding. Sampson and Clark [57] revealed another reason: the use of limited data to support claims and difficulties in expressing reasons or refutation because they did not understand [58]. Students who have difficulty making structured arguments based on scientific concepts (theories, principles and laws) do not understand the correct components of scientific argumentation [59]. It was in line with Marsita *et al.* [60] they found some students always expressed their arguments. Some students were insisted on sharing arguments. It proved the existence of influential factors toward argumentation skills. Marsita *et al.* [60] found the influence of argumentation. It consisted of prior knowledge. It was the condition in which students could share arguments after obtaining prior knowledge. It also referred to a learning experience in which students would argue once they noticed something concerning the discussed problems.

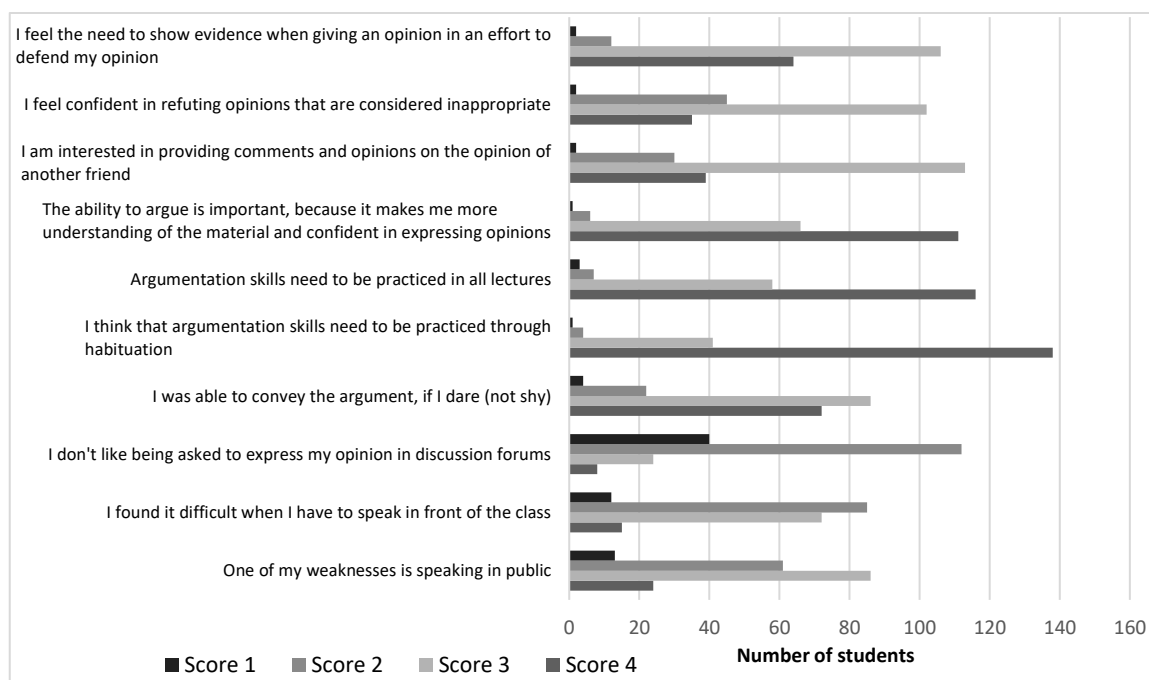


Figure 3. Recapitulation of students' perception measurement results on scientific argumentation skills

#### 4. CONCLUSION

This research applied survey typed cross-sectional design. The research respondents were 184 students even semester in 2020/2021 academic year. The applied instrument was the validity process. The validity results showed that the test and questionnaire instruments were valid, relevant, and reliable to measure the skills. The student science argumentative skill profile showed that the students did not reach level 5. Then, 52% of students could reach level 3 while 35% of students reached level 2. It meant their skills to argue in a complex manner had not included the mastery of providing complete data. The students' perceptions showed that they were interested in expressing their arguments and confidence while expressing their arguments. The results suggested the science educators prepare teacher candidates with argumentative scientific skills by developing learning innovation.

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