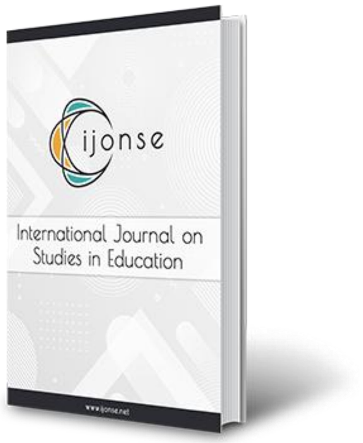

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Exploring Science Teachers’ Knowledge, Attitudes, and Practices toward Scientific Argumentation in Science Education

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Exploring Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in Science Education

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Abstract

Scientific argumentation has gained increasing attention as a potent inquiry-based strategy that fosters students' scientific literacy, critical thinking, and engagement. This study explores the knowledge, attitudes, and practices of secondary science teachers (SSTs) in Central Luzon, Philippines, regarding scientific argumentation within the evolving context of blended and remote learning environments. Using both quantitative and qualitative research designs, data were gathered from 190 SSTs through a validated self-reported survey ($\alpha = .81$) and open-ended responses. Quantitative data were analyzed using descriptive statistics, t-tests, ANOVA, Pearson correlation, and regression analysis, while qualitative responses were thematically examined using Quirkos software. Findings revealed that SSTs possess a very high level of knowledge of scientific argumentation, hold generally favorable attitudes, especially in terms of motivation and classroom engagement, and implement argumentation strategies to a great extent in their teaching. However, significant differences emerged based on demographic factors such as teaching experience, sex, and school type. Furthermore, strong positive correlations were found among teachers' knowledge, attitudes, and practices, highlighting the need for targeted professional development. Notably, limited resources and insufficient access to training emerged as barriers to consistent implementation. The program offers actionable insights for advancing science education and highlights the need for sustained support, curriculum alignment, and accessible resources to embed scientific argumentation in diverse learning contexts. Hence, the study proposes the *TEACH MINDS* professional development program to translate scientific argumentation practices into classroom instruction, bridging gaps in practice and fostering discourse-rich, student-centered learning. Grounded in social constructivist principles, *TEACH MINDS* aims to enhance science teachers' pedagogical competence through workshops, collaborative lesson design, peer coaching, technology integration, and reflective practice.

Introduction

The promotion of scientific literacy has become the primary goal of science education (National Research Council, 1996; K to 12 Science Curriculum, 2016). Scientific literacy entails students' ability to demonstrate scientific knowledge, attitudes, and process skills and includes their ability to generate, articulate, and evaluate evidence-based knowledge (Antonio & Prudente, 2021; Norris & Phillips, 2003). However, considering the current remote learning setup, it has become a challenge for science teachers to create learning experiences that will support students' development of scientific literacy. Hence, science teachers are highly encouraged to adhere to student-centered instructional strategies that can simultaneously leverage their practices and advance students' development of scientific literacy.

Scientific argumentation has emerged as a potent strategy in cultivating students' scientific literacy (Çınar & Bayraktar, 2014; Demirbağ & Günel, 2014; Lambert & Bleicher, 2017; Kim & Roth, 2018;). The process of scientific argumentation reflects the core practices of science in developing and verifying scientific knowledge (Duschl, 2008). When used in the classroom, it provides avenues for students to actively engage in the social practice of using evidence and reasoning to build and advance scientific knowledge (Berland & Hammer, 2012; Fishman *et al.*, 2017; Manz, 2015). This will eventually help them recognize the nature of science as a dynamic process, where ideas are continuously investigated and revised (Diehl, 2000). In this process, students develop a scientific argument that has three main components: claim, evidence, and reasoning. The claim refers to the answer to the inquiry, while the evidence includes information that supports the claim. On the other hand, the reasoning justifies the evidence by associating it with a specific scientific concept or theory (Sengul, 2019; Sampson & Schleigh, 2013; McNeill, 2011).

Numerous literature and studies provided positive evidence of the impact of scientific argumentation in developing students' scientific literacy. In the study of Ural and Gençoğlan (2020), the argumentation-based science teaching approach has been found to be effective in improving students' academic achievement and science process skills. However, no significant change has been found in students' attitudes toward the class. This was supported by the study of Kızkapan and Bektaş (2021), who established the effectiveness of epistemologically-enriched argumentation instruction in improving students' academic achievement, which was attributed to the processes of forming arguments, defending arguments, and negotiation of meanings during argumentation. It has also been an effective instructional strategy to support students' understanding of the content (Sari and Islami, 2020; Sampson & Blanchard, 2012) and engagement (Sengul, 2009).

Moreover, recent studies suggest the effectiveness of scientific argumentation in developing students' critical thinking skills (Sari & Islami, 2020; Giri & Paily, 2020; Hasançebi *et al.*, 2021; Foutz, 2018). In the study of Giri and Paily (2020), scientific argumentation integrated within the Think-Read-Group-Share-Reflect approach facilitated the attainment of students' critical thinking skills. Moreover, the STEM-supported argumentation-based inquiry approach has been recognized for enhancing students' academic achievement, scientific creativity, and reflective thinking skills for problem-solving (Hasançebi *et al.*, 2021). In a meta-analysis, the positive impact of scientific argumentation in enhancing students' reasoning skills based on existing empirical studies was also noted (Sari & Islami, 2020).

The beneficial impact of scientific argumentation can be associated with the conceptual and cognitive, epistemic, and social practices that transpire inside the classroom (Sampson, Enderle, & Walker, 2012). The conceptual and cognitive practices of scientific argumentation can be seen from the students' ability to improve their knowledge, evaluate alternative claims, willingness to attend to erroneous data, level of skepticism, and appropriate reasoning strategies. Meanwhile, the epistemic practices focus on their ability to use and evaluate evidence, participate in the discourse using scientific theories, laws, or models, and utilize the language of science to communicate their ideas. Finally, social practices of scientific argumentation entail their ability to communicate and interact with the other students, being reflective and respectful about what they say, and willingness to solicit and discuss ideas introduced by others.

Although argumentation has increasingly been recognized as an effective strategy in facilitating students' development of scientific literacy, there is still limited information about science teachers' knowledge, attitudes, and practices towards science argumentation. In the study of Choi *et al.* (2021), middle and high school science teachers' views of argument in scientific inquiry and argument-driven science instruction were examined. Results suggested that although most teachers seemed to understand the relationship between argument and scientific inquiry, several challenges hindered their implementation of argument-based instruction. These include the lack of students' experience, knowledge, and willingness to participate in argumentation. Aside from these, the teachers' lack of understanding and experience, lack of class time, entrance exam-oriented class, and number of students were the other impeding factors to their practice of scientific argumentation in their classes. While the study revealed science teachers' views regarding argumentation inquiry, the generalizability of results may not be applicable due to the small sample size and that it only involved the use of questionnaires.

Similarly, the study of Kim, Tan, and Talaue (2013) found the same challenges that science teachers encounter in implementing inquiry-based learning strategies, like scientific argumentation. In addition, Mcneill and Knight (2013) suggested teachers' difficulties in supporting scientific argumentation in their classes. They noted several challenges, including the skills of applying the reasoning component of argumentation and crafting argumentation questions or inquiry. Moreover, Sampson and Blanchard (2012) determined teachers' perspectives on integrating scientific argumentation in science instruction. The findings of their study indicated that although they perceived argumentation as a useful strategy, they had concerns regarding their students' low argumentation skills. When these studies are taken together, the integration of scientific argumentation in the classroom has become a challenging practice due to the impeding factors that involve teachers, students, and the learning environment.

To address these concerns, a little number of studies attempted to improve teachers' pedagogical knowledge and skills towards scientific argumentation. Topalsan (2020) implemented and evaluated a professional training program for science teachers regarding the infusion of scientific argumentation into virtual laboratory applications. After participation in the program, positive changes in science teachers' views and favorable perceptions of argumentation-based virtual laboratory activities were noted from the teacher and the students. Meanwhile, in the study of Fishman (2017), both teachers and students achieved statistically significant improvements in their science discourse practices after participation in a professional development program about scientific argumentation.

Undoubtedly, teachers have an important role in creating learning experiences that foster a culture of scientific argumentation (McNeill & Pimentel, 2010; Venville & Dawson, 2010). In the literature, teachers' knowledge and attitudes towards instructional strategies have a critical influence on their application of such in their classes (DiBiase & McDonald, 2015; Choi *et al*., 2021; Kang 2008). Considering the positive impact of scientific argumentation in teaching and learning, it is therefore important to gain insights on science teachers' current knowledge, attitudes, and practices towards scientific argumentation. In the Philippines, no study has examined the aforementioned variables among Filipino science teachers. Hence, it is critical to explore such to inform the development and implementation of professional development programs, with the aim of enhancing teachers' technological and pedagogical content knowledge of scientific argumentation in the context of a blended learning environment.

Research Questions

This study aimed to assess secondary science teachers' (SSTs) knowledge, attitudes, and practices towards scientific argumentation. Specifically, it sought to answer the following questions:

1. How may the knowledge of SSTs on scientific argumentation be described in terms of nature of scientific argumentation, roles of teachers and students, and impact on students' learning?
2. How may the attitudes of SSTs towards scientific argumentation be described in terms of knowledge dependence, motivation, resources, classroom management, and systemic restrictions?
3. How may the practices of SSTs on scientific argumentation be described in terms of conceptual and cognitive aspect, epistemic aspect, and social aspect?
4. Are there significant differences in the SSTs' knowledge, attitudes, and practices towards scientific argumentation when grouped according to profile?
5. Are there significant relationships among SSTs' knowledge, attitudes, and practices towards scientific argumentation?
6. What professional development program can be designed and implemented to enhance SSTs' pedagogical competence in effectively integrating scientific argumentation practices into science teaching?

Method

Research Design

A descriptive research design was employed to determine SSTs' knowledge, attitudes, and practices on scientific argumentation. Both quantitative and qualitative data were collected and analyzed. Quantitative data were obtained from a validated online survey questionnaire, while the qualitative data were culled from the responses to the open-ended questions included in the final section of the questionnaire.

Research Locale and Participants

This study was conducted in four (4) school divisions in the Central Luzon region of the Philippines. These school divisions serve a total of 24 cities and municipalities. The respondents of the study included those who were teaching Science subjects at the secondary level. Purposive sampling was employed in choosing the respondents. After data clean-up, a total of 190 survey forms were obtained and included in the analysis. The following figures present the profile of the 190 SSTs who served as the respondents in the study. In terms of sex, the majority of the SSTs were females (72.1%), while 27.9% were males (see Figure 1).

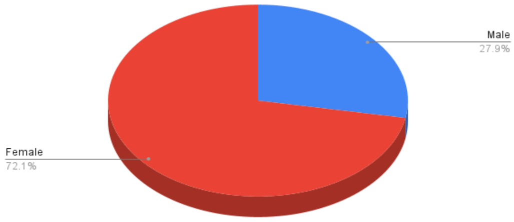

Figure 1. Profile of the Respondents in terms of Sex

When it comes to age, 23.7% of the SSTs were in the age group of 20-25 years old; 13.2% were in the age group of 26-30 years old; 19.5% were in the age group of 31-35 years old; 18.4% were in the age group of 36-40 years old; 8.9% were in the age group of 41-45 years old; 7.4% were in the age group of 46-50 years old; 5.8% were in the age group of 51-55 years old, and; 3.2% were in the age group of 56-60 years old (see Figure 2).

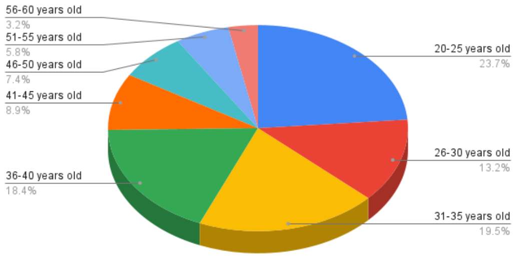

Figure 2. Profile of the Respondents in terms of Age

Concerning their length of experience, 34.2% of the SSTs had 1-5 years of teaching experience; 24.7% had 6-10 years of experience; 17.9% had 11-15 years; 7.4% had 16-20 years; 5.8% had 21-25 years, and; 10% had more than 25 years of teaching experience. (see Figure 3).

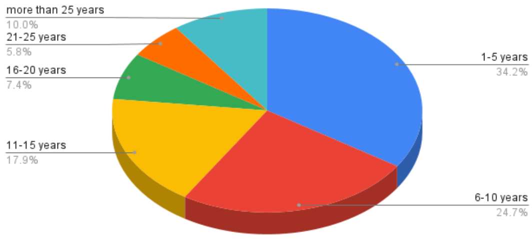

Figure 3. Profile of the Respondents in terms of Length of Teaching Experience

With regard to the type of school, the majority of the surveyed SSTs came from public high schools (81.1%), while 18.9% of the SSTs came from private high schools (see Figure 4). As regards the level of teaching assignment, the majority of the SSTs were teaching at the junior high school level (80.5%), while 19.5% were teaching at the senior high school level (see Figure 5).

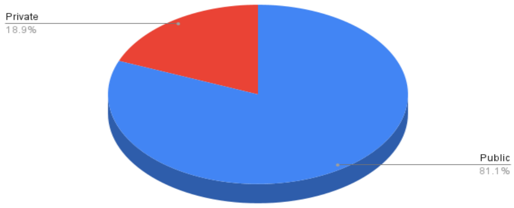

Figure 4. Profile of the Respondents in terms of Type of School

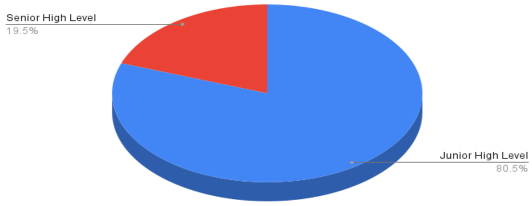

Figure 5. Profile of the Respondents regarding the Level of Teaching Assignment

In relation to the average number of students handled in class, the majority of the SSTs were handling more than 40 students (65.8%); 25.3% of the SSTs handled 31-40 students; 6.8% handled 21-30 students, and; 1.6% handled 11-20 students (see Figure 6).

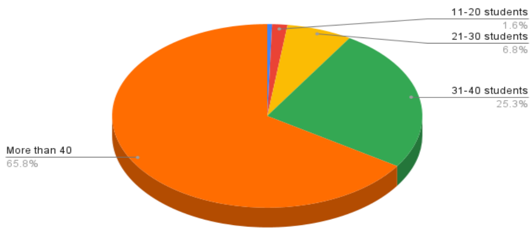

Figure 6. Profile of the Respondents in terms of the Average Number of Students

As for the highest educational attainment, the majority of the SSTs were bachelor's degree holders (77.4%) while the remaining 22.6% had master's degrees (see Figure 7).

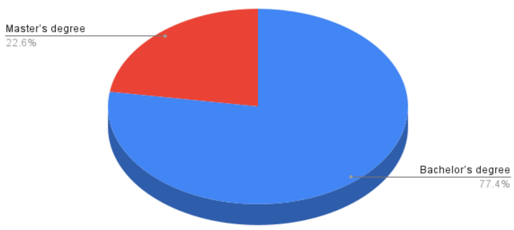

Figure 7. Profile of the Respondents in terms of the Highest Educational Attainment

Research Instrument

Development of the Assessment of Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation (ASTKAP-SA) Questionnaire

The Assessment of Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific

Argumentation (ASTKAP-SA) questionnaire is a self-reported survey instrument developed to serve the purpose of this study. This questionnaire was crafted based on existing research instruments and literature on scientific argumentation. Specifically, the ASTKAP-SA questionnaire consisted of 51-items in the form of statements divided into four (4) parts. The first part of the questionnaire dealt with the SSTs' demographic profile, including their sex, age, length of teaching experience, type of school, level of teaching assignment, average number of students they handled, and highest educational attainment.

The second section centered on SSTs' knowledge of scientific argumentation. Statements in this scale were adapted from existing literature and instruments (e.g. Sampson, Enderle, & Walker, 2012). Meanwhile, the third section aimed to gauge SSTs' attitudes towards scientific argumentation, in which statements were adapted from the PRIMAS (Promoting Inquiry-based Learning in Mathematics and Science Education) survey instrument (Dorier & Maaß, 2012). The final section included statements that pertained to SSTs' practices on the different aspects of scientific argumentations (Sampson, Enderle, & Walker, 2012).

The ASTKAP-SA questionnaire was then transformed into an online survey questionnaire through Google Forms. In the online survey questionnaire, SSTs were asked to indicate their level of agreement or disagreement through a five-point Likert scale with the 14 statements that generally apply to their knowledge of scientific argumentation, and through a four-point Likert scale with the 16 and 21 statements that focused on their attitudes and practices on scientific argumentation, respectively. At the final section of the questionnaire, SSTs were asked to identify the instructional strategies they had been using to promote scientific argumentation in their science class. SSTs were also invited to answer three (3) open-ended questions, revolving around their knowledge, attitudes, and practices of scientific argumentation.

Validation and Reliability Analysis of the ASTKAP-SA Questionnaire

The ASTKAP-SA questionnaire was content-validated by five (5) Science education experts holding masterate and doctorate degrees in science education and one (1) language expert completing a doctorate degree in language education. The content validation of the questionnaire was performed with respect to the clarity and direction of items, presentation, and organization of items, suitability of items, adequateness of the content, attainment of purpose, objectiveness, and scale and evaluation rating. The overall weighted mean of 4.76 (SD=0.53) reflects the high acceptability of the questionnaire.

Moreover, the feedback and suggestions of the expert validators were taken into account to improve the questionnaire. After content validation, the questionnaire was pilot-tested to 30 SSTs from both public and private high schools. They were asked to give their feedback about the questionnaire; all of them did not have any problem or confusion with the instrument, which they found to be clear and simple. Reliability analysis was then performed using the IBM Statistical Package for Social Sciences (SPSS) software. The initial draft of the questionnaire consisted of a total of 55 statements in the knowledge, attitudes, and practices scale. However, four (4) statements were removed to increase the reliability of the questionnaire. The reliability analysis obtained acceptable values of Cronbach's alpha, as seen in Table 1.

Table 1. Test of Reliability

Scales	Dimensions	Number of items	Reliability
knowledge of scientific argumentation	nature and definition of scientific argumentation	6	.759
	roles of teachers and students in scientific argumentation	4	
	impact of scientific argumentation on students' learning	4	
attitudes towards scientific argumentation	knowledge dependence	2	.776
	motivation	5	
	resources	2	
	classroom management	4	
	systemic restrictions	3	
practices on scientific argumentation	conceptual and cognitive	8	.886
	epistemic	7	
	social	6	

Data Collection Procedures

Prior to the data collection, permission to conduct the study was sought from the respective Division Offices of the Department of Education. After approval of the request, the ASTKAP-SA online survey questionnaire was distributed to the school principals and then disseminated to their respective science teachers through the head teachers. The help of the program supervisor was also sought to disseminate the online survey questionnaire to the science teachers through a Google Forms link. At the beginning of the survey questionnaire, SSTs were asked to read the consent form, informing them of the purpose of the study, study procedures, duration, risks, benefits, and confidentiality. They were reminded that participation in the survey is voluntary and were asked to signify their willingness to participate through the consent form. If the respondents signified their willingness to participate, they were asked to answer the following sections of the questionnaire that aimed to assess their current knowledge, attitudes, and practices on scientific argumentation. SSTs were also asked to answer open-ended questions included in the survey.

Data Analysis

Both quantitative and qualitative data were gathered and tabulated from the ASTKAP-SA online survey questionnaire through Google Forms. For quantitative data, descriptive statistics were mainly used to describe the SSTs' demographic profile and determine their knowledge, attitudes, practices on scientific argumentation. In the survey questionnaire, the item statements were mostly positively worded.

A few items were negatively formulated; in such a case, the items were reverse-scored, where the numerical scoring scale runs in the opposite direction. The weighted mean rating for each statement and the overall weighted mean are verbally interpreted as shown in Table 2. After which, the corresponding standard deviations were used to describe the homogeneity of the responses.

Table 2. Verbal Interpretation

Scale	Rating	Verbal Interpretation
knowledge of scientific argumentation	4.20-5.00	Very High
	3.40-4.19	High
	2.60-3.39	Moderate
	1.80-2.59	Low
	1.00-1.79	Very Low
attitudes towards scientific argumentation	3.50-4.00	Highly favorable
	2.50-3.49	Favorable
	1.50-2.49	Unfavorable
	1.00-1.49	Highly unfavorable
practices on scientific argumentation	4.20-5.00	To a very great extent
	3.40-4.19	To a great extent
	2.60-3.39	To a moderate extent
	1.80-2.59	To a limited extent
	1.00-1.79	To a very limited extent

Prior to employing further statistical analyses, normality testing of the data from the research instrument was conducted. The Shapiro-Wilk result confirms that the data gathered from the study showed no deviation from the normality ($p > .05$). Moreover, Pearson correlation and regression analysis were performed to explore the relationships among SSTs' knowledge, attitudes, and practices on scientific argumentation. Additionally, inferential statistics, mainly independent-samples t-test and analysis of variance (ANOVA), were used to determine significant differences in SSTs' knowledge, attitudes, and practices on scientific argumentation relative to their profile. As for the qualitative data, the thematic analysis procedure of Braun and Clarke (2006) was used to analyze the SSTs' responses culled from the open-ended questions included in the online survey questionnaire. Answers were transcribed and thematically analyzed through the use of a qualitative software Quirkos. The results of the thematic analysis were used to corroborate the quantitative results.

Results and Discussion

Secondary Science Teachers' Knowledge on Scientific Argumentation

In the online survey questionnaire, SSTs were asked to indicate their level of agreement or disagreement through a five-point Likert scale with the 14 statements that generally apply to their knowledge of scientific argumentation, particularly on the nature and definition of scientific argumentation, roles of teachers and students in scientific argumentation, and its impact on students' learning. The following tables present detailed descriptions of the results for each dimension. In terms of the nature and definition of scientific argumentation, Table 3 reflects that SSTs strongly agreed that scientific argumentation is a process of validating or refuting a claim based on evidence and reasons (M=4.40; SD=.67). They were found to have a knowledge of the basic components of a scientific argument, which consists of a claim, evidence, and reasoning. They agreed that the claim refers to the explanation or an answer to a research question (M=4.18; SD=.78). They strongly agreed that the evidence refers to the data or findings that can be used to support the claim (M=4.46; SD=.67) and that the reasoning must explain the relevance of the evidence by linking it to a specific scientific concept, principle, or underlying assumption (M=4.49; SD=.65). As an instructional strategy, SSTs strongly agreed that scientific argumentation is a dialogic process that can build students' ideas (M=4.47; SD=.68); hence, they recognize it as an inquiry-based approach to teaching and learning (M=4.54; SD=.66). Going into details, the nature of scientific argumentation as an inquiry-based approach garnered the highest mean (M=4.54; SD=.66) while the claim as an essential component of a scientific argument recorded the lowest mean (M=4.18; SD=.78) among the statements. According to Hanri *et al.*, (2017), some teachers were unfamiliar with the components of scientific argument, including the claim component that provides an explanation or an answer to the research question. In totality, the weighted mean for the SSTs' knowledge of the nature and definition of scientific argumentation dimension is 4.42 with a standard deviation of .56. This indicates that SSTs have a very high level of knowledge of the nature and definition of scientific argumentation.

Table 3. Teachers' Knowledge on the Nature and Definition of Scientific Argumentation (N=190**)**

No.	**Statements**	**SD %**	**D %**	**U %**	**A %**	**SA %**	**Mean**	**Std. Dev.**
1	Scientific argumentation is a process of validating or refuting a claim based on evidence and reasons.	.5	.5	5.8	44.7	48.4	4.40	.67
2	In a scientific argument, the claim is an explanation or an answer to a research question.	1.6	2.1	6.8	55.3	34.2	4.18	.78
3	In a scientific argument, the evidence refers to the data or findings used to support the claim.	.5	.5	5.3	40	53.7	4.46	.67
4	In a scientific argument, reasoning explains the relevance of the evidence by linking it to a specific concept, principle, or underlying assumption.	.5	1.1	2.1	41.6	54.7	4.49	.65
5	Scientific argumentation is a dialogic process that builds students' ideas.	.5	.5	5.8	37.9	55.3	4.47	.68
6	Scientific argumentation is an inquiry-based approach to teaching and learning.	.5	.5	4.2	34.2	60.5	4.54	.66
	Weighted Mean						**4.42**	**.56**

Note: Strongly Disagree (SD); Disagree (D); Uncertain (U); Agree (A); Strongly Agree (SA)

As for the essential roles of teachers and students during scientific argumentation, shown in Table 4, SSTs strongly agreed that their students' role is to develop a scientific argument that provides and supports a claim with authentic evidence (M=4.46; SD=.69). They strongly agreed that when students are engaged in scientific argumentation, they are afforded with an opportunity to evaluate other scientific explanations (M=4.44; SD=.67) and express their privately-held ideas (M=4.21; SD=.85). Moreover, they strongly agreed that it is an essential task for teachers to facilitate and scaffold the exchange of ideas among students during scientific argumentation (M=4.49; SD=.67). Interestingly, the crucial facilitating role of the teachers in scientific argumentation garnered the highest mean (M=4.49; SD=.67) among the statements. This important role of the teachers leads to the active involvement of the students in the scientific argumentation process (Hanri *et al.*, 2017; Venville & Dawson, 2010). Meanwhile, the lowest mean (M=4.21; SD=.85) was seen in the students' role of expressing their privately-held ideas during scientific argumentation. In summary, the weighted mean of 4.40 with a standard deviation of .59 implies that SSTs possess a very high level of knowledge on the roles of teachers and students in scientific argumentation.

Table 4. Teachers' Knowledge on the Roles of Teachers and Students in Scientific Argumentation (N=190)

No.	Statements	SD %	D %	U %	A %	SA %	Mean	Std. Dev.
1	In scientific argumentation, students develop an argument that provides and supports a claim with genuine evidence.	.5	1.1	4.7	39.5	54.2	4.46	.69
2	In scientific argumentation, students evaluate scientific explanations.	.5	.5	5.3	41.6	52.1	4.44	.67
3	Scientific argumentation allows students to express their privately-held ideas.	1.6	2.6	10.5	43.7	41.6	4.21	.85
4	In scientific argumentation, teachers facilitate and scaffold the exchange of ideas among students.	.5	1.1	3.7	37.9	56.8	4.49	.67
	Weighted Mean						**4.40**	**.59**

Note: Strongly Disagree (SD); Disagree (D); Uncertain (U); Agree (A); Strongly Agree (SA)

As displayed in Table 5, SSTs strongly agreed that when students are actively involved in scientific argumentation, they will be able to understand the dynamic nature of scientific knowledge (M=4.51; SD=.67), enhance their critical thinking skills (M=4.62; SD=.68), and improve their reasoning skills (M=4.68; SD=.60). Consequently, they disagreed that it can create a classroom community that places less emphasis on evidence (M=2.36; SD=1.40). Among these statements, the highest mean was noted in the statement about the beneficial impact of scientific argumentation in improving students' reasoning skills (M=4.68; SD=.60), whereas the lowest mean (M=2.36; SD=1.40) was recorded in the negative statement that scientific argumentation places less emphasis on evidence. These suggest that SSTs recognized that scientific argumentation puts great importance on generating claims that are supported with evidence and reasoning. Altogether, the weighted mean for the SSTs' knowledge on the impact of scientific argumentation on students' learning dimension is 4.04 with a standard deviation of .55. This means that SSTs hold a high level of knowledge regarding the potential benefits of scientific argumentation on students' learning.

Table 5. Teachers' Knowledge on the Impact of Scientific Argumentation on Students' Learning (N=190)

No.	Statements	SD %	D %	U %	A %	SA %	Mean	Std. Dev.
1	Scientific argumentation helps students understand the dynamic nature of scientific knowledge.	.5	.5	5.3	34.7	58.9	4.51	.67
2	Scientific argumentation enhances students' critical thinking skills.	1.1	.5	3.2	25.8	69.5	4.62	.68
3	Scientific argumentation improves students' reasoning skills.	.5	.5	2.1	24.2	72.6	4.68	.60
4	Scientific argumentation creates a classroom community that	36.3	27.4	12.6	11.1	12.6	2.36	1.40

places less emphasis on evidence.			
Weighted Mean		**4.04**	**.55**

Note: Strongly Disagree (SD); Disagree (D); Uncertain (U); Agree (A); Strongly Agree (SA)

In general, the overall weighted mean for the knowledge scale is 4.31 with a standard deviation of .50. Among the different dimensions under the knowledge scale, it can be seen that the highest weighted mean was computed in the nature and definition of scientific argumentation dimension (M=4.42; SD=.56), followed by the roles of teachers and students in scientific argumentation (M=4.40; SD=.59) and the impact of scientific argumentation on students' learning (M=4.04; SD=.55) dimensions. These results indicate that although SSTs have a very high level of knowledge of scientific argumentation in terms of its nature and the crucial roles of teachers and students, some SSTs still lack knowledge of its impact in improving the teaching and learning process. The results of this study contradict the existing belief that teachers had insufficient knowledge of scientific argumentation (Aydeniz & Ozdilek, 2015; Prihandayu & Paidi, 2020; Sampson & Blanchard, 2012; Hanri *et al*., 2017). SSTs' responses to the open-ended question are summarized in Table 6.

Table 6. Thematic Analysis of the SSTs' Responses to the Open-ended Question

Codes	Categories	Themes
justifying ideas or thought; validating a claim based on reasons; explaining arguments; Socratic method; questioning ideas; proving something or wrong; develops and refine knowledge; debate about scientific learning; solving real-life problems; observation and explanation; scientific reasoning	scientific practices	Scientific argumentation is an inquiry-based teaching approach.
discovery approach; effective strategy; interactive instruction; student-centred learning; student active participation; effective strategy	student-centred instruction	
students learning from each other; explaining thoughts and ideas; sharing of ideas/thoughts	collaborative sharing of ideas	Scientific argumentation is an effective instructional strategy that facilitates and promotes students' understanding of the scientific concepts through collaborative and critical discourse.
facilitates understanding of the lesson; requires students' knowledge; deepening students knowledge; assessing students' understanding	facilitating students' understanding	
critical thinking skills, creative thinking skills, reasoning skills, higher-order thinking skills	promotion of higher-order thinking skills	Scientific argumentation improves students' higher-order thinking skills.

At the end of the online survey questionnaire, SSTs were asked to answer the open-ended question that focused on their current knowledge about scientific argumentation. To substantiate the quantitative findings, the thematic analysis of the SSTs' responses provided further evidence of their strong knowledge of scientific argumentation. As one of the emerging themes from their responses, SSTs regard scientific argumentation as an inquiry-based teaching approach. The following are some of the responses of the SSTs:

SST 66: "*Scientific argumentation is a process that occurs when there are multiple ideas or claims to* *discuss and reconcile. An argument includes a claim supported by evidence and reasoning, and students engage to evaluate and critique competing arguments."*

SST 182: "*This approach involves active participation of the students in explaining and expressing their arguments. They need to justify their claims through evidence."*

SST 188: "Scientific argumentation is questioning existing knowledge and providing logical reasons for accepting it. It provokes systematic investigation and experiments to prove or disprove a concept. It allows critical and reflective thinking yet respecting the ideas of others, especially when it is backed by scientific evidence. It promotes collaboration and open-mindedness to work on a specific principle."

Another theme that emerged from the SSTs' responses reflects the effectiveness of the instructional strategy in facilitating and promoting students' understanding of the scientific concepts through collaborative and critical discourse. To elaborate on this theme, the following are sample responses of the SSTs:

SST 49: "Scientific argumentation invites students to become open to their ideas, to voice out their thoughts which are supported by evidence that they read or research."

SST 52: "Scientific argumentation is an approach wherein students can understand the lesson/concepts based on the data gathered /ideas presented through students' explanation. It is a discussion based on facts and evidence."

SST 162: *"Scientific argumentation can be used as an instructional approach in a way that it will allow students to express his/her ideas which can be agreeable or disagreeable to his/her classmate..."*

Furthermore, SSTs recognized that scientific argumentation has a potential role of improving students' higher-order thinking skills. The following are some verbatim responses of the SSTs:

SST 174: "*It provides an avenue for the development of critical thinking skills. Students do not merely adhere to memorization-based knowledge or rote learning in science*."

SST 163: "*...scientific argumentation will help the students to improve their critical thinking skills to be intellectually engaged throughout the discussion.*"

SST 84: "*It may broaden the ideas of students to fully understand science concepts using scientific evidence and reflect on better reasoning in explaining the concept*."

The word cloud below from the Quirkos software depicts the most recurring words from the responses of the SSTS (see Figure 8).

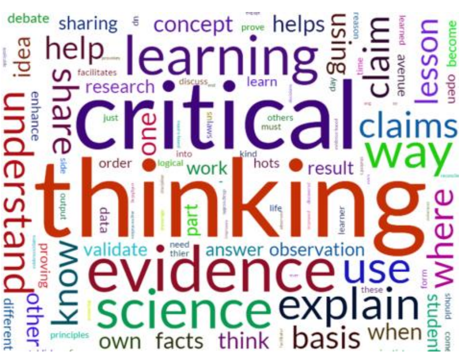

Figure 8. Quirkos Wordcloud

Secondary Science Teachers' Attitudes towards Scientific Argumentation

To explore SSTs' attitudes towards scientific argumentation, they were asked to indicate their level of agreement or disagreement through a four-point Likert scale with the 16 statements that focused on their attitudes in terms of knowledge dependence, motivation, resources, classroom management, and systemic restrictions. The following tables present detailed descriptions of the results for each dimension. As regards knowledge dependence, SSTs agreed that engaging in scientific argumentation requires students' use of extensive content knowledge (M=3.39; SD=.64) (see Table 7). They disagreed that this instructional strategy is not effective among underperforming students (M=2.43; SD=.89). However, more than half of the SSTs (52%) showed agreement that it may not be effective with underperforming students. This is similar to the results of the study of Sampson and Blanchard (2012) who revealed teachers' concerns with underperforming students due to their poor argumentation skills. Taken together, the weighted mean for this dimension was 2.91 with a standard deviation of .49, suggestive of their favorable attitudes when it comes to knowledge dependence.

Table 7. Teachers' Attitudes towards Scientific Argumentation in terms of Knowledge Dependence (N=190)

No.	Statements	SD %	D %	A %	SA %	Mean	Std. Dev.
1	Scientific argumentation requires students to have extensive content knowledge.	1.1	5.3	47.4	46.3	3.39	.64
2	Scientific argumentation is not effective with underperforming students.	17.9	30.5	42.1	9.5	2.43	.89
	Weighted Mean					**2.91**	**.49**

Note: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA)

As for motivation, SSTs showed an agreement that scientific argumentation can be an effective instructional approach to improve students' motivation (M=3.48; SD=.57) and thus can be used to address students' learning difficulties (M=3.28; SD=.65) (see Table 8). Moreover, they strongly agreed that they would like to use scientific argumentation as a strategy to create opportunities for students to express and explain their ideas (M=3.66; SD=.51) and make their lessons more interesting on the part of the students (M=3.57; SD=.54).

Table 8. Teachers' Attitudes towards Scientific Argumentation in terms of Motivation (N=190)

No.	Statements	SD %	D %	A %	SA %	Mean	Std. Dev.
1	Scientific argumentation is an effective approach to improve students' motivation.	0	3.7	44.2	52.1	3.48	.57
2	Scientific argumentation is well-suited to approach students' learning problems.	1.6	5.8	55.3	37.4	3.28	.65
3	I would like to create opportunities for students to express and explain their ideas.	.5	0	32.6	66.8	3.66	.51
4	I would like to teach my lessons through scientific	.5	.5	40.0	58.9	3.57	.54

	argumentation to make them more interesting.						
5	I prefer not to use scientific argumentation because it will bore my students.	8.9	14.2	42.1	34.7	3.03	.92
	Weighted Mean					**3.41**	**.41**

Note: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA)

Among the statements in this dimension, the highest mean (M=3.66; SD=.51) was noted in the statement of intending to use scientific argumentation to help their students express and explain their ideas, while the negative statement of disinterested attitude of using scientific argumentation got the lowest mean (M=3.03; SD=.92). Here, seventy-five percent (75%) of the SSTs remarked that they do not prefer to use scientific argumentation for it will cause boredom in their classes. This contradicts the previous studies that established the effectiveness of scientific argumentation in increasing students' motivation and engagement (Chen et al., 2019; Chen et al., 2016). All in all, the motivation dimension obtained a weighted mean of 3.41 with a standard deviation of .41, reflecting SSTs' favorable attitudes towards the use of scientific argumentation in their classes.

Pertaining to the available resources, SSTs showed disagreement that there are insufficient teaching and learning resources (e.g. learning materials) that they can use to promote scientific argumentation (M=2.35; SD=.86) in their classes (see Table 9). They also disagreed that they did not have access to any adequate professional development programs involving scientific argumentation (M=2.16; SD=.86). However, the weighted mean of 2.26 with a standard deviation of .78 shows that they have unfavorable attitudes when it comes to available resources and programs that can support them in utilizing scientific argumentation practices in their classes. This conforms to the study of Ramnarain and Hlatswayo (2018) who established the importance of the availability of teaching and learning resources that support scientific argumentation. In line with the classroom management, SSTs agreed that managing groupworks would be difficult (M=2.57; SD=87) (see Table 10).

Table 9. Teachers' Attitudes towards Scientific Argumentation in terms of Resources (N=190)

No.	Statements	SD %	D %	A %	SA %	Mean	Std. Dev.
1	I do not have sufficient resources (e.g. learning materials) that support scientific argumentation.	16.8	39.5	35.3	8.4	2.35	.86
2	I do not have access to any adequate professional development programs involving scientific argumentation.	22.1	47.9	22.1	7.9	2.16	.85
	Weighted Mean					**2.26**	**.78**

Note: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA)

Table 10. Teachers' Attitudes towards Scientific Argumentation in terms of Classroom Management (N=190)

No.	Statements	SD %	D %	A %	SA %	Mean	Std. Dev.
1	I think group work is difficult to manage when using scientific argumentation in class.	12.6	30.0	44.7	12.6	2.57	.87

2	I worry that classroom management would be more challenging when using scientific argumentation.	13.2	37.4	38.9	10.5	2.47	.85
3	I do not feel confident with scientific argumentation.	9.5	23.2	52.1	15.3	2.73	.83
4	I worry about my students getting lost and frustrated in their learning.	14.2	33.2	38.4	14.2	2.53	.91
	Weighted Mean					**2.56**	**.705**

Note: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA)

SSTs disagreed that classroom management would be more challenging when using scientific argumentation (M=2.47; SD=.85) in their classes. They agreed that they do not feel confident with scientific argumentation (M=2.73; SD=.83) and worry about their students' learning progress, where they could get lost and frustrated (M=2.53; SD=.91). This result may be attributed to the SSTs' lack of pedagogical content knowledge in the implementation of scientific argumentation in their classes. In all, the weighted mean for this dimension is 2.56 with a standard deviation of .705, reflecting SSTs' favorable attitudes towards classroom management when employing scientific argumentation.

In terms of system restrictions, SSTs agreed that their students do not take assessments that reward scientific argumentation (M=2.63; SD=.82) and that the curriculum does not encourage scientific argumentation (M=2.67; SD=.87) (see Table 11). Moreover, they disagreed that using scientific argumentation is time-consuming (M=2.46; SD=.92). When these statements are examined, the highest mean (M=2.67; SD=.87) was recorded in the statement about the incoherence of scientific argumentation in the curriculum, while the lowest mean was recorded in the statement describing it as a time-consuming strategy (M=2.46; SD=.92). While inquiry-based teaching strategies, with emphasis on evidence in constructing explanations, are being advocated in the K to 12 science curriculum, these findings revealed that SSTs do not recognize the relevance of scientific argumentation as an inquiry-based teaching strategy in relation to existing science curriculum. Nevertheless, the weighted mean for this dimension was computed at 2.59 with a standard deviation of .73 still indicates their favorable attitudes when it comes to systematic restrictions.

Table 11. Teachers' Attitudes towards Scientific Argumentation in terms of Systemic Restrictions (N=190)

No.	Statements	SD %	D %	A %	SA %	Mean	Std. Dev.
1	My students do not take assessments that reward scientific argumentation.	10.5	27.4	51.1	11.1	2.63	.82
2	The curriculum does not encourage scientific argumentation.	11.1	25.8	47.9	15.3	2.67	.87
3	Using scientific argumentation is time-consuming.	16.3	34.7	35.8	13.2	2.46	.92
	Weighted Mean					**2.59**	**.73**

Note: Strongly Disagree (SD); Disagree (D); Agree (A); Strongly Agree (SA)

In summary, the overall mean for the attitude scale is 2.84 with a standard deviation of .44, suggesting that SSTs hold favorable attitudes towards scientific argumentation. However, the decreasing magnitude of weighted means under this scale were as follows: motivation (M=3.41; SD=.41), knowledge dependence (M=2.91; SD=.49); systemic restrictions (M=2.59; SD=.73); classroom management (M=2.58; SD=.70), and; resources (M=2.25; SD=.78). From all the dimensions under the attitude scale, the resources dimension returned the lowest weighted mean (M=2.25; SD=.78), indicating SSTs' unfavorable attitudes. Although her study focused on inquiry-based learning, Gutierrez (2015) elucidated that the lack of support and training for teachers and the availability of teaching and learning resources could be one of the several factors that hindered the enactment of inquiry-based strategies, like scientific argumentation, in science classes.

Table 12. Thematic Analysis of the SSTs' Responses to the Open-ended Question

Codes	**Category**	**Theme**
improves reasoning skills; develops students' research skills; helps students make decisions; recognizes scientific practices; stimulates students' curiosity; allows self-discovery; validates ideas with facts; allows students develop scientific judgments; enhances students' scientific inquiry; develops students' logical thinking; eradicate fake judgements; open mindedness	promotion of students' higher-order thinking skills	Scientific argumentation has a beneficial impact on the teaching and learning process.
real-life application; expound scientific ideas; improves academic performance and confidence; fosters students' interaction; supports independent learning; supports collaboration; assess students knowledge; gaining more information and knowledge; facilitates deeper learning	facilitates students' meaningful learning of scientific concepts	

Furthermore, the thematic analysis of the SSTs' responses to the open-ended question strengthens the quantitative findings that SSTs have positive attitudes towards scientific argumentation (see Table 12). As the emerging theme, SSTs stated that scientific argumentation has a beneficial impact on the teaching and learning process because it promotes students' higher-order thinking skills and facilitates students' meaningful learning of scientific concepts. The following are some of the SSTs' responses:

> SST 66: "*Scientific argumentation is beneficial to students' learning because it increases their willingness to access scientific information, guides them to think like scientists, and increases their academic success*."
>
> SST 176: "*Scientific argumentation would be beneficial to students' learning because it supports scientific discussions that help the learners to improve their critical thinking skills and comprehension*."
>
> SST 189: "*Scientific argumentation enables students to know how new knowledge is generated and validated by scientists as well as the important theories, laws, and unifying concepts of the various disciplines in order to understand science as a way of knowing*."

However, by going through the other responses, there are some SSTs who hold unfavorable attitudes towards scientific argumentation.

SST 62: "*Scientific argumentation will not be beneficial because not all students know how to explain and defend facts and opinions.*"

SST 101: "*I thought the use of scientific argumentation would be beneficial only to those students with advanced knowledge and ideas or to those with higher-order thinking skills as one of their intelligence*."

SST: "*Scientific argumentation will only be beneficial if given enough resources.*"

As reflected in Figure 9, the word cloud from the Quirkos software captures the most recurring words from the responses of the SSTS.

Figure 9. Quirkos Wordcloud

Secondary Science Teachers' Practices of Scientific Argumentation

Finally, SSTs were also asked to respond with the 16 statements that generally apply to their scientific argumentation practices in terms of conceptual and cognitive, epistemic, and social dimensions. The following tables present detailed descriptions of the results for each dimension. With regards to the conceptual and cognitive practices of scientific argumentation, SSTs expressed that they encourage their students to generate claims or explanations (M=3.86; SD=.77) and discuss alternative claims or explanations (M=3.72; SD=.75) in their classes to a great extent (see Table 13). They also encourage them to modify their claims or explanations when they notice an inconsistency in the information (M=3.83; SD=.80) and become skeptical of ideas and information (M=3.54; SD=.86) to a great extent. Additionally, to a great extent of practice, they ask their students to provide reasons when supporting (M=4.14; SD=.69) and challenging an idea (M=4.09; SD=.71), and support their ideas based on reasoning (M=4.18; SD=.68). Besides, SSTs said that they rarely encourage their students to memorize scientific concepts or ideas (M=2.39; SD=.85). From these statements, the highest mean (M=4.14; SD=.69) was seen in the SSTs' practice of asking students to support their ideas based on reasoning, while the lowest mean (M=2.39; SD=.85) was noted in memorizing scientific concepts or ideas. These findings support the nature of scientific argumentation as an inquiry-based teaching strategy, where it does not advocate for rote learning but for the active construction of knowledge through collaborative and dialogic interactions (Memiş & Çevik, 2018; Venville & Dawson, 2010). All in all, the conceptual and cognitive practice dimension of scientific argumentation returned a mean of 3.72 with a standard deviation of .48. This means that SSTs demonstrate a great extent of cognitive and conceptual practices of scientific argumentation in their classes.

Table 13. Teachers' Conceptual and Cognitive Practices of Scientific Argumentation (N=190)

No.	In teaching science, how often have you asked your students to:	N %	R %	O %	VF %	A %	Mean	Std. Dev.
1	generate claims or explanations?	0	2.6	29.5	46.8	21.1	3.86	.77
2	discuss alternative claims or explanations?	0	2.6	38.4	43.7	15.3	3.72	.75
3	modify their claims or explanations when they notice an inconsistency in the information?	.5	4.7	24.7	51.6	18.4	3.83	.80
4	become skeptical of ideas and information?	1.1	7.9	41.1	36.3	13.7	3.54	.86
5	provide reasons when supporting an idea?	0	0	17.4	51.1	31.6	4.14	.69
6	provide reasons when challenging an idea?	0	1.1	17.9	51.6	29.5	4.09	.71
7	support their ideas based on reasoning?	0	0	15.8	50	34.2	4.18	.68
8	memorize scientific concepts or ideas?	13.2	44.2	33.7	7.9	1.1	2.39	.85
	Weighted Mean						**3.72**	**.48**

Note: Never (N); Rarely (R); Occasionally (O); Very Frequently (VF); Always (A)

Focusing on the epistemic practices of scientific argumentation, SSTs noted that they do encourage their students to evaluate others' claims or explanations (M=3.89; SD=.72), use evidence to support their claims (M=4.09; SD=.70), and challenge others' claims (M=3.93; SD=.83) to a great extent (see Table 14).

Table 14. Teachers' Epistemic Practices of Scientific Argumentation (N=190)

No.	In teaching science, how often have you asked your students to:	N %	R %	O %	VF %	A %	Mean	Std. Dev.
1	evaluate others' claims or explanations?	0	1.6	26.8	52.6	18.9	3.89	.72
2	use evidence to support their claims?	0	.5	18.4	52.6	28.4	4.09	.70
3	use evidence to challenge others' claims?	1.1	2.6	23.7	47.4	25.3	3.93	.83
4	examine the evidence used by others?	1.1	2.1	34.2	42.6	20	3.78	.82
5	evaluate how the evidence was interpreted?	.5	0	29.5	48.9	21.1	3.90	.74
6	use scientific theories, laws, or models to support ideas?	0	1.1	18.9	45.8	34.2	4.13	.75
7	use scientific theories, laws, or models to challenge ideas?	0	1.6	21.1	46.8	30.5	4.06	.76
	Weighted Mean						**3.97**	**.64**

Note: Never (N); Rarely (R); Occasionally (O); Very Frequently (VF); Always (A)

Moreover, they ask them to examine the evidence used (M=3.78; SD=.82) and evaluate how the evidence was interpreted (M=3.90; SD=.74). They also require them to make use of scientific theories, laws, or models to support their own ideas (M=4.13; SD=.75) and challenge others' ideas (M=4.06; SD=.76) to a great extent. Looking into the statements, the highest mean (M=4.13; SD=.75) was computed for the epistemic practice of encouraging students to use scientific theories, laws, or models to support their ideas, while the lowest mean (M=3.78; SD=.82) was obtained in the practice of asking students to examine the evidence used by other students. In scientific argumentation, students communicate, critique, and refine evidence-based arguments that provide an answer to a question. Students also need to provide a reasoning to justify the evidence by associating it with specific scientific theory, law, or model (Sampson et al., 2012; Sengul, 2019; Sampson & Schleigh, 2013; McNeill, 2011). Moreover, the result suggests that SSTs should provide opportunities for their students to take a critical lens of the evidence presented by their classmates as a result of their inquiry-based investigations. In summary, the weighted mean of 3.97 and a standard deviation of .64 denotes SSTs' adherence to epistemic practices of scientific argumentation to a great extent.

Finally, as for the social practices of scientific argumentation, SSTs remarked that they encourage their students to express their ideas (M=4.26; SD=.74) and respect what their classmates had to say (M=4.42; SD=.66) to a very great extent (see Table 15). According to them, this can be achieved by reminding their students to never negatively respond to the ideas of others (M=3.62; SD=1.27). Moreover, they encourage them to become reflective about their understanding (M=4.04; SD=.72) and of how they know (M=4.01; SD=.72) to a great extent. Aside from this, they allow their students to discuss ideas when they are introduced into the conversation (M=3.98; SD=.74) to a great extent. From these statements, the social practice of encouraging students to become respectful of other students' ideas obtained the highest mean (M=4.42; SD=.66). Meanwhile, the social practice of asking students to negatively respond to the ideas of others had the lowest mean (M=3.62; SD=1.27). However, it can be gleaned that some SSTs allow their students to respond to the ideas of their other classmates negatively. This may be attributed to the SSTs' understanding of scientific argument, which is usually linked to a debate. It has to be noted that the purpose of scientific argumentation is to provide a learning environment that puts emphasis on the discursive process of negotiating ideas and meanings, contrary to debates. Taken together, the social practice of scientific argumentation returned a weighted mean of 4.05 with a standard deviation of .54, demonstrating SSTs' great extent of social practices of scientific argumentation.

Table 15. Teachers' Social Practices of Scientific Argumentation (N=190)

No.	In teaching science, how often have you asked your students to:	N %	R %	O %	VF %	A %	Mean	Std. Dev.
1	become reflective about what they know?	0	1.1	21.1	51.1	26.8	4.04	.72
2	become reflective about how they know?	0	.5	24.2	49.5	25.8	4.00	.72
3	respect what each other had to say?	0	0	9.5	38.9	51.6	4.42	.66
4	negatively respond to the ideas of others?	5.3	18.9	18.4	23.2	34.2	3.62	1.27
5	discuss an idea when it was introduced into the conversation?	.5	0	25.3	49.5	24.7	3.98	.74
6	express their ideas?	0	.5	16.3	39.5	43.7	4.26	.74
	Weighted Mean						**4.05**	**.54**

Note: Never (N); Rarely (R); Occasionally (O); Very Frequently (VF); Always (A)

Generally, the overall weighted mean for the practice scale was 3.90 with a standard deviation of .47. The overall weighted mean implies that SSTs demonstrate a great extent of cognitive and conceptual, epistemic, and social practices of scientific argumentation in their classes. From these three dimensions, it can be seen that the highest weighted mean was recorded in the social practices dimension (M=4.05; SD=.54), followed by the epistemic practices dimension (M=3.97; SD=.64), whereas the lowest weighted mean was noted in the conceptual and cognitive practices dimension (M=3.72; SD=.48). This result conforms to the previous literature establishing scientific argumentation as an avenue for collaborative knowledge construction with emphasis on mutual respect and reciprocity, thereby enabling students recognize the importance of collaboration in the dialogic exchange of ideas towards advancing their understanding (Songsil et al., 2019; Gutierez, 2019). This result calls for a greater emphasis of SSTs' conceptual and cognitive practices in their classes to facilitate students utilize their conceptual structures (e.g. scientific theories) and cognitive processes during the process of scientific argumentation.

Table 16. Thematic Analysis of the SSTs' Responses on the Open-ended Question

Codes	**Category**	**Theme**
develops students' reasoning skills; develops students' learning; fosters students' interaction; innovative strategies; useful; collaborative learning;	positive impact of scientific argumentation to teaching and learning	Scientific argumentation practices can still be employed in a blended learning environment through appropriate teaching and learning activities.
appropriate teaching and learning activities; proper instructions; requires teachers' guidance; art of questioning; online classes; learning environment; willingness of the students; writing virtual debate; reflective summary; depends on the learning competencies	teaching and learning experiences	

Considering the current educational set-up, SSTs were asked of the possible integration of scientific argumentation practices within a blended learning environment. The majority of them said that scientific argumentation practices can still be employed in the current set-up. The following are some of their responses:

> SST 46: "*It is possible because teachers need to become equipped with strategies that may develop the reasoning skills of the students.*"
>
> SST 77: "*Yes, because we need some innovative ways on how to execute our teaching particularly this time of the pandemic*."
>
> SST 82: "*Yes, because it may always be integrated in every mode of the teaching-learning process. For example, modules include different activities to develop the scientific argumentation skills of students.*"

However, some SSTs showed uncertainty of the use of scientific argumentation within a blended learning environment. They mentioned that there are several factors that may hinder the integration of scientific argumentation in the online learning set-up, which point to students' insufficient resources and knowledge, poor internet connectivity, lack of social interaction, reliability of students' learning, teachers' lack of pedagogical knowledge, and lack of teaching and learning resources. To elaborate on this, the following are some of the responses of the SSTs:

> SST 61: "*Due to the situation of most students wherein there is a poor internet connection in their areas, I think this scientific argumentation will not be as effective as what we are expecting to be.*"
>
> SST 175: "*Until there is no social interaction (face-to-face) among learners, the scientific argument will not be useful. Interacting with other people has proven to be quite effective in assisting learners to organize their thoughts, reflect on their understanding, and find gaps in their reasoning*. "
>
> SST 170: "*Some modifications should be done on the process (time allotment, instructional*

materials/resources, etc.) Orientation for teachers should be done as well to make the implementation smooth and effective."

SST 188: "*It will be very hard and limited. Implementation of scientific argumentation is in question since it will be difficult to determine whether the ideas are original or taken from someone or something*."

The word cloud below from the Quirkos software captures the most recurring words from the responses of the SSTs.

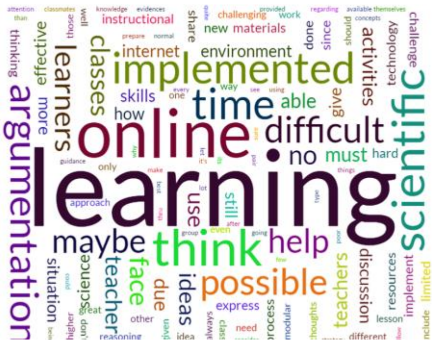

Figure 10. Quirkos Wordcloud

Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation

Based on Table 17, it can be seen that male SSTs had higher means in knowledge (M=4.42; SD=.41) and practice scales (M=4.07; SD= .47), in comparison to female SSTs. Meanwhile, female SSTs obtained a higher mean in the attitudes scale as compared to male SSTs. To determine significant differences in their knowledge, attitudes, and practices on scientific argumentation, an independent sample t-test was used. Results revealed significant differences between male and female SSTs' knowledge and practices ($p < .05$) on scientific argumentation, indicating that male SSTs had significantly higher knowledge of and demonstrated a greater extent of scientific argumentation practices than female SSTs. No significant difference ($p > .05$), however, was found between the male and female SST' attitudes toward scientific argumentation, suggestive of similar attitudes towards scientific argumentation.

Table 17. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Sex (N=190)

	Male			**Female**				
	n	**M**	**SD**	**n**	**M**	**SD**	**t**	**p**
Knowledge	53	4.42	.41	137	4.26	.53	2.223	**.028**
Attitudes	53	2.78	.45	137	2.86	.44	-1.283	.203
Practices	53	4.07	.47	137	3.83	.46	3.089	**.003**

Note: N = 190 respondents (male n=53; female n=137)

In terms of age, it was noted that the SSTs in the age group 20-25 years old returned the highest mean when it comes to knowledge (M=4.44; SD=.32) and attitudes (M=2.92; SD=.47) towards scientific argumentation, whereas SSTs in the age group 26-30 years old recorded the highest mean with regard to practices on scientific argumentation (M=4.11; SD=.42). Analysis of variance was used to determine differences in their knowledge, attitudes, and practices on scientific argumentation according to age group (see Table 18). Findings underscored that no significant differences ($p > .05$) were found in SSTs' knowledge and attitudes toward scientific argumentation, suggesting that SSTs, regardless of age, possess very high knowledge and hold favorable attitudes toward scientific argumentation. However, a significant difference ($p < .05$) was found regarding the SSTs' extent of practices of scientific argumentation. When means were analyzed, younger teachers demonstrated a significantly greater extent of scientific argumentation practices than the older teachers.

Table 18. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Age (N=190)

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	2.529	7	.361	1.441	.191
Knowledge	Within Groups	45.639	182	.251		
	Total	48.169	189			
	Between Groups	.962	7	.137	.684	.685
Attitudes	Within Groups	36.570	182	.201		
	Total	37.532	189			
	Between Groups	5.676	7	.811	4.092	**.000**
Practices	Within Groups	36.072	182	.198		
	Total	41.748	189			

As reflected in Table 19, it can be seen that private SSTs consistently registered higher means in knowledge (M=4.46; SD=.32), attitudes (M=2.92; SD=.43), and practices scales (M=4.03; SD=.42), in comparison to public SSTs. The results from the independent sample t-test revealed that a significant difference existed between public and private SSTs' knowledge on scientific argumentation ($p < .05$), indicating that the private SSTs had significantly better knowledge than public SSTs. In addition to this, no significant difference ($p > .05$) was found between public and private SST' attitudes towards and practices on scientific argumentation. This result indicates that both public and private SSTs exhibited the same attitudes and had a similar extent of practice of scientific argumentation.

Table 19. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Type of School (N=190)

	Public			**Private**			**t**	**p**
	n	**M**	**SD**	**n**	**M**	**SD**		
Knowledge	154	4.27	.53	36	4.46	.31827	-2.747	**.007**
Attitudes	154	2.82	.45	36	2.92	.42994	-1.309	.196
Practices	154	3.87	.48	36	4.03	.42046	-1.992	.051

As displayed in Table 20, it can be gleaned that the senior high school SSTs returned higher means in the knowledge (M=4.47; SD=.30) and practice scales (M=4.05; SD=.37) relative to the junior high school SSTs. The results from the independent sample t-test revealed significant differences between junior high and senior high SSTs' knowledge and practices on scientific argumentation ($p < .05$), indicating that the senior high SSTs had significantly better knowledge of and a greater extent of practice of scientific argumentation than junior high school SSTs. Moreover, no significant difference ($p > .05$) was found between junior high and senior high SSTs' attitudes towards scientific argumentation.

Table 20. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Level of Teaching Assignment (N=190)

	Junior High School Level			**Senior High School Level**			**t**	**p**
	n	**M**	**SD**	**n**	**M**	**SD**		
Knowledge	153	4.27	.54	37	4.47	.30	-2.970	**.004**
Attitudes	153	2.85	.45	37	2.80	.43	.666	.508
Practices	153	3.86	.48	37	4.05	.37	-2.585	**.012**

When means were compared according to the average number of students in class, SSTs handling an average number of 21-30 students consistently obtained the highest means in knowledge (M=4.65; SD=.23), attitudes (M=2.97; SD=.49), and practices (M=4.16; SD=.39) scales (see Table 21). The ANOVA results, however, revealed insignificant differences in SSTs' knowledge, attitudes, and practices on scientific argumentation ($p > .05$), suggesting that SSTs regardless of the number of students handling in class, exemplify high level of knowledge, favorable attitudes, and a great extent of practice of scientific argumentation in their classes.

Table 21. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Average Number of Students in Class (N=190)

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Knowledge	Between Groups	1.769	4	.442	1.763	.138
	Within Groups	46.400	185	.251		
	Total	48.169	189			
Attitudes	Between Groups	.533	4	.133	.666	.616
	Within Groups	36.999	185	.200		
	Total	37.532	189			
Practices	Between Groups	1.730	4	.433	2.000	.096
	Within Groups	40.018	185	.216		
	Total	41.748	189			

When weighted means were compared as regards the length of teaching experience, SSTs with 1-5 years of teaching experience had the highest means in knowledge (M=4.43; SD=.35) and practices (M=4.02; SD=.46) scales as compared to the other groups. Meanwhile, SSTs with 21-25 years of teaching experience recorded the highest mean in terms of attitudes towards scientific argumentation (M=2.92; SD=.38) (see Table 22)

Table 22. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Length of Teaching Experience (N=190)

		Sum of Squares	df	Mean Square	F	Sig.
Knowledge	Between Groups	3.515	5	.703	2.896	**.015**
	Within Groups	44.654	184	.243		
	Total	48.169	189			
Attitudes	Between Groups	1.018	5	.204	1.026	.404
	Within Groups	36.514	184	.198		
	Total	37.532	189			
Practices	Between Groups	3.308	5	.662	3.167	**.009**
	Within Groups	38.440	184	.209		
	Total	41.748	189			

ANOVA results revealed that there were significant differences in terms of their knowledge and practices of scientific argumentation when grouped according to the length of teaching experience. These suggest that early career teachers had a significantly higher level of knowledge of scientific argumentation and a greater extent of practice of scientific argumentation. This result is in contrast to the study of Erduran *et al*. (2016) that more experienced teachers can provide beginning teachers with some indication of how to build their own repertoire in teaching argumentation. On the other hand, no significant difference was found in terms of SSTs' attitudes towards scientific argumentation, implying that teachers have similar attitudes towards argumentation. Although their focus was on inquiry-based learning, this result is parallel to the previous findings of Silm *et al.* (2017) and Xie and Sharif (2014), suggesting that attitudes toward inquiry-based learning, which are likely to hold true for scientific argumentation, were similar for teachers with different length of teaching experience.

As for the highest educational attainment, SSTs with only bachelor's degrees obtained higher means in knowledge (M=4.43; SD=.35) and attitude scales (M=2.84; SD=.43) as compared to SSTs with master's degrees (see Table 23). Meanwhile, SSTs with master's degrees obtained a higher mean in the practice scale. Independent sample t-test results revealed a statistically significant difference in SSTs' knowledge of scientific argumentation when grouped according to the highest educational attainment, implying that SSTs with only bachelor's degrees possess a significantly better knowledge of scientific argumentation than SSTs with master's degrees. Moreover, no significant differences were found in their attitudes and practices, indicative that SSTs, regardless of their highest educational attainment, had favorable attitudes towards and a great extent of practice of scientific argumentation.

Table 23. Differences in Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation in terms of Highest Educational Attainment (N=190)

	Bachelor's degree			Master's degree			t	p
	n	M	SD	n	M	SD		
Knowledge	147	4.3732	.39495	43	4.0864	.73450	2.459	**.018**
Attitudes	147	2.8389	.42747	43	2.8372	.50833	.019	.985
Practices	147	3.8873	.46774	43	3.9380	.48110	-.612	.543

Relationships among the Secondary Science Teachers' Knowledge, Attitudes, and Practices on Scientific Argumentation

To explore any relationship among the variables being studied, Pearson product-moment correlation was computed. Results showed statistically significant relationships among SSTs' knowledge, attitudes, and practices of scientific argumentation. Specifically, SSTs' knowledge has a statistically low positive correlation with their attitudes (r=.228, n=190, p=.002) and practices towards scientific argumentation (r=.366, n=190, p=.000). Similarly, SSTs' attitudes had a statistically low positive correlation with their practices (r=0.335, n=190, p=.000); hence, these findings indicate that possessing knowledge about scientific argumentation is positively related to attitudes and practices towards scientific argumentation.

Furthermore, multiple regression analysis suggests that SSTs' knowledge and attitudes towards scientific argumentation significantly predicted their scientific argumentation practices, F(2, 187) = 23.553, p =.000, R2 = .201. The results of the present study adhere to the previous studies, establishing science teachers' knowledge and attitudes as critical factors that influence their application of inquiry-based learning in their classes (DiBiase & McDonald, 2015; Choi et al., 2021; Kang 2008). Although they focused on primary in-service teachers, the study of Xie and Sharif (2014) obtained similar results on the significant relationships among teachers' knowledge on the nature of science, attitude and belief towards inquiry teaching with the implementation of inquiry-based learning. They concluded that teachers' knowledge, attitude, and beliefs are the main predictors for implementing inquiry-based learning. Considering that scientific argumentation is an inquiry-based approach to teaching, the result of the present study provides a significant input for the planning and implementation of professional development programs that will further capacitate teachers with essential pedagogical knowledge of scientific argumentation, which might also eventually further cultivate their positive attitudes towards it and strengthen their scientific argumentation practices.

The Proposed *TEACH MINDS* Professional Development Program

In response to the findings of this study, the *TEACH MINDS* (Technology Integration, Metacognition, and Argument-Driven Inquiry for Secondary Science Teachers) professional development program is proposed as a comprehensive framework to enhance science teachers' pedagogical competence in integrating scientific argumentation into classroom practice (see Figure 11). Rooted in social constructivist theory, *TEACH MINDS* emphasizes knowledge construction through meaningful interaction, discourse, and collaborative inquiry (Vygotsky, 1978). It is also aligned with empirical evidence underscoring that sustained, collaborative, and practice-oriented professional development significantly improves teachers' instructional practices and student learning outcomes (Desimone & Garet, 2015; Fishman et al., 2017).

The *TEACH MINDS* program is structured as a cyclical, multi-phase framework designed to progressively build teachers' competence and confidence in implementing argumentation-based instruction. It begins with Awareness, where teachers develop a foundational understanding of the epistemic, cognitive, and social dimensions of scientific argumentation. This is followed by Exploration, where they examine instructional models, analyze classroom scenarios, and observe best practices that demonstrate effective use of claims, evidence, and reasoning (Sampson & Blanchard, 2012; McNeill, 2011).

Figure 11. The *TEACH MINDS* Professional Development Model

The Integration phase focuses on contextualizing these strategies into actual lesson planning, where teachers co-design inquiry-based learning experiences that embed argumentation tasks, incorporate digital tools, and align with curriculum standards. This stage also includes peer coaching and collaborative lesson studies, enabling teachers to refine their instructional designs based on feedback and evidence from classroom practice (Berland & Hammer, 2012; Ramnarain & Hlatswayo, 2018). During Deliberation, teachers critically reflect on instructional outcomes, discuss challenges and successes with peers, and adapt their strategies based on student responses and learning evidence. Finally, the Action phase consolidates these insights into sustained classroom practices, leading to the creation of discourse-rich learning environments that cultivate students' critical thinking, evidence-based reasoning, and scientific literacy.

A key feature of *TEACH MINDS* is its emphasis on metacognition, encouraging teachers to engage in continuous self-assessment and reflective practice, and on technology integration, leveraging digital platforms to support scientific discourse in both face-to-face and blended learning settings. Additionally, the program fosters a community of practice, a professional learning space that nurtures collaboration, knowledge sharing, and ongoing professional growth (Garet et al., 2001). Through this sustained and holistic approach, teachers move beyond superficial adoption of argumentation strategies to become confident facilitators of evidence-based scientific inquiry. Altogether, the *TEACH MINDS* program provides a structured pathway for transforming teaching practices, bridging the gap between theory and classroom implementation, and positioning scientific argumentation as a core pedagogical approach in science education.

Conclusion

This study investigated secondary science teachers' (SSTs) knowledge, attitudes, and practices towards scientific argumentation within the context of Central Luzon, Philippines. The findings revealed that SSTs generally possess a very high level of knowledge of scientific argumentation, especially in terms of its nature and the roles of teachers and students. While their understanding of its impact on students' learning was slightly lower, it was still considered high overall. Teachers also expressed favorable attitudes towards scientific argumentation, particularly in its ability to motivate learners and create meaningful classroom interactions. However, concerns regarding the availability of resources, access to professional development, and classroom management challenges were notable. Despite these concerns, SSTs reported employing scientific argumentation to a great extent, especially in fostering social and epistemic practices among students. Significant differences were observed in SSTs' knowledge, attitudes, and practices when analyzed by demographic variables such as sex, age, school type, and teaching experience. Notably, younger and less experienced teachers demonstrated higher levels of knowledge and more extensive practices. Furthermore, positive correlations were identified among knowledge, attitudes, and practices, with knowledge and attitudes significantly predicting the extent of teachers' argumentation practices. These findings underscore the importance of enhancing pedagogical support for teachers, particularly in designing inquiry-based lessons that integrate argumentation strategies. While teachers generally recognize the value of scientific argumentation, systemic barriers—such as curriculum alignment, assessment limitations, and lack of training—continue to hinder consistent implementation.

Implications and Recommendations

The findings of this study highlight several key areas for educational improvement. First, there is a need to design and implement sustained professional development programs that equip teachers with practical strategies for integrating scientific argumentation into both blended and face-to-face learning environments. These programs should focus not only on theoretical understanding but also on classroom application through modeling, peer collaboration, and reflection. In this regard, the *TEACH MINDS* professional development program has been conceptualized for empowering science educators. Anchored on the integration of technology, metacognition, and argument-driven inquiry, this program can provide structured, sustained training that guides teachers through a continuum of learning experiences, ranging from workshops and demonstration lessons to collaborative lesson design and reflective practice. Through peer feedback sessions, co-planning of inquiry-driven lessons, and opportunities to experiment with innovative teaching strategies, the *TEACH MINDS* program can enable teachers to translate theory into practice, strengthen their instructional skills, and foster classroom environments where scientific argumentation becomes a central component of student learning.

In addition, the development and dissemination of targeted teaching and learning resources, such as scaffolding tools, sample lesson plans, and activity guides, are essential to support teachers, particularly those in resource-constrained schools. Aligning curriculum and assessment practices with argumentation-based instruction is also critical. This includes revising curricular content to emphasize evidence-based reasoning and updating assessment frameworks to reward scientific discourse and reasoning skills. Moreover, the enthusiasm and adaptability of early-career teachers can be maximized by offering mentorship opportunities and professional learning communities where best practices in scientific argumentation can be shared and sustained. These combined efforts will help embed scientific argumentation more deeply into science education practices.

Limitations and Future Directions

Despite its valuable insights, this study is subject to certain limitations. It relied primarily on self-reported data, which may not fully reflect actual classroom practices due to possible response biases. Additionally, the use of purposive sampling limits the generalizability of the findings to a broader population of science teachers. Future research should consider triangulating data through classroom observations, interviews, or lesson artifacts to obtain a more comprehensive picture of how scientific argumentation is enacted. Longitudinal studies and intervention-based research designs would also be valuable to examine the long-term impact of professional development on teaching practices and student outcomes.

In conclusion, fostering a culture of scientific argumentation in science classrooms goes beyond building awareness—it requires intentional, systemic support through well-aligned training, resources, and educational policies. Only through such coordinated efforts can teachers be truly empowered to cultivate scientific reasoning and inquiry among their students.

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