Review

A Systematic Analysis: Trends in Research on Scientific Discourse and Argumentation Published by (ESERA) Through 2011–2021

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Review

A Systematic Analysis: Trends in Research on Scientific Discourse and Argumentation Published by the European the Conference on Research in Science Education (ESERA) through 2011–2021

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Abstract: The Next Generation Science Standards (NGSS) highlight the importance of students engaging in scientific discourse and argumentation as a core part of students' learning development. A key Science and Engineering Practice outlined in the NGSS is "Engaging in Argument from Evidence," which inspires students to compare and evaluate claims, critically analyze the reasoning and evidence supporting different situations, and construct well-reasoned arguments to support or refute scientific explanations. Thus, the primery objective of this paper is to identify patterns in scientific argumentation research, including the keywords, objectives, research methods, and instruments used in studies published in the ESERA conference proceedings from 2011 to 2021. A mix of quantitative and qualitative content analysis methodology was employed to examine the trends in argumentation and discourse studies published by ESERA. The results indicated that the proportion of articles focused on argumentation and scientific discourse ranged between 3.8% and 6.6%, with the highest publication rate occurring in 2017 at 6.6%. In terms of keywords, no clear consistent pattern was observed in their occurrence across the argumentation and discourse articles; however, keywords related to classroom and discourse, argumentation, context and content, thinking skills, and learning processes were the most common. These articles primarily focused on addressing several objectives; however, the articles addressing investigating discourse analysis and argumentation, and exploring student learning and understanding comprised more than 60% of the contentt. In terms of research methodologies, qualitative approaches were the most commonly used, comprising more than three-quarters of the studies. The leading data collection tools included document and transcript analyses and case studies. The findings can provide evidence-based indicators of the growing importance of research in discourse and argumentation, which is increasingly recognized as crucial due to its strong connection with the emergence of new standards such as the Next-Generation Science Standards (NGSS). The NGSS standards emphasize the significance of scientific and engineering practices, particularly those involving the construction of evidence-based arguments.

Keywords: argumentation; scientific discourse; science education; research trends; systematic analysis

1. Introduction

The study of argumentation has a lengthy history that can be traced back to ancient Greek writings on logic (proof), rhetoric (persuasion), and dialectic (inquiry), particularly the works of Aristotle (Van Eemeren et al., 2015). Scientific argumentation involves language-based practices

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where scientists construct and evaluate each other's arguments, negotiating meaning across various representational forms like writing, drawings, charts, and tables (Klein, 2006). This argumentative process is a spoken, social, and rational activity aimed at convincing a reasonable critic to accept a particular perspective or position (Van Eemeren & Grootendorst, 2004). In the scientific context specifically, argumentation is a means of verifying or refuting claims by providing reasons and evidence that align with the values and norms of the scientific literacy (Norris et al., 2007).

Based on the definitions of scientific argumentation, Toulmin developed a model that includes elements such as making claims, providing supporting evidence, and addressing counterarguments (Toulmin, 2003). Jimenez-Aleixandre & Erduran (2007) further emphasized the connection between argumentation and discourse, describing it as a collaborative process for constructing and evaluating knowledge claims using experiential or theoretical evidence. Discourse refers to verbal expressions, conversations, and ways of representing, thinking, and exchanging ideas (Rapanta et al., 2021; Rapanta, 2019; Sadler, 2006). The National Council of Teachers of Mathematics (NCTM) emphasizes that mathematics classrooms should become communities of inquiry where students collaboratively explore, formulate, and critique mathematical ideas in order to enhance conceptual understanding (Ferrini-Mundy,2000).

Both argumentation and discourse have become central fundamentals of science education (Gonzalo et al., 2019). Scientists use argumentation to generate explanations, models, and theories (Toulmin, 2003). Thus, discourse and argumentation are considered essential to the progress of scientific knowledge and scientific discourse (Gonzalo et al., 2019). Consequently, students should be engaged in the implications of discourse and argumentation strategies through explicit teaching suitable to their level, which can be achieved by implementing both task structuring and modeling (Passmore & Svoboda, 2012). The teaching and learning of discourse and argumentation should be part of the framework of science education literature, which in turn should take into consideration community practices (Jimenez-Aleixandre & Erduran, 2007; National Research Council, 2012; NGSS Lead States, 2013; Sadler, 2006). This leads to providing suitable evidence for each argument, in turn enhancing creative, critical, and analytical skills. Jiménez-Aleixandre and Erduran (2007) suggested a model (Figure 1) of how argumentation is interconnected and supports various elements of other variables such as epistemic criteria, theory choice, commitment to evidence, and critical thinking.

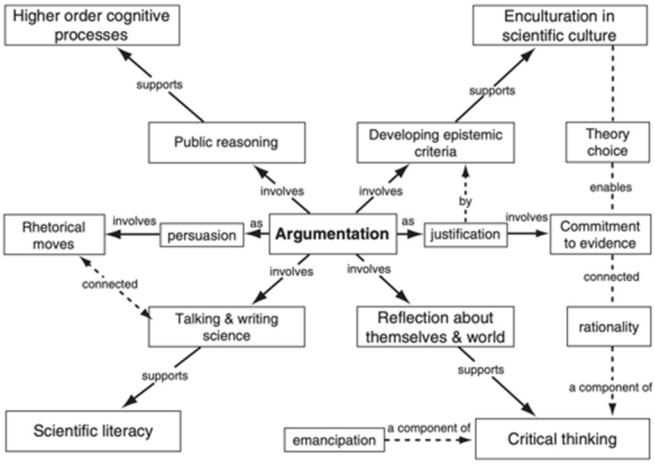

Figure 1. Potential contribution from argumentation (Jiménez-Aleixandre & Erduran, 2007, p. 11).

Approaches such as inquiry-based instruction, discovery learning, problem-solving, and hands-on activities encourage students to engage in scientific practices including working with variables, designing experiments, and testing hypotheses (Alfarraj & Althubyani, 2023; Adúriz-Bravo & Chion, 2017). Effective science education requires reconceptualizing teaching practices to better integrate scientific discourse and argumentation (Aldahmash & Alfarraj, 2022; Driver et al., 2000). Engaging students in scientific discourse and argumentation has been proven to foster their scientific

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literacy and participation in core scientific activities, indicating that these elements should play a central role in science education (Gonzalez et al., 2019; Jimenez-Aleixandre & Erduran, 2007).

To deeply comperhend science concepts and effectively engage in scientific processes, it is essential for students to develop strong discourse and argumentation skills, such as reasoning, debating, constructing arguments, and critiquing them (Chen, Hand, & Park, 2016; Ford, 2012). These skills are just as important as building critical thinking and scientific knowledge, as they enable deeper, more meaningful learning of science concepts (Bricker & Bell, 2008; Osborne, 2010; Osborne et al., 2012, 2013). For this to happen, teachers should acquire the ability to enhance students' discourse and argumentation skills in their science teaching. By recognizing the importance of these skills, researchers have focused on ways to effectively teach discourse and argumentation in science education (Driver et al., 2000; Jimenez-Aleixandre & Erduran, 2007; Kaya et al., 2012; Kaya, 2013; Lu & Zhang, 2013; McNeill & Krajcik, 2006; Venville & Dawson, 2012; Zohar, 2008) in order to enhance scientific literacy. In addition, numerous studies have contributed to our understanding of discourse and argumentation by shedding light on different dimensions and models of argumentation (Erduran et al., 2004; Foong & Daniel, 2010, 2013; Toulmin, 2003; Venville & Dawson, 2012).

On the other hand, students often face challenges in using discourse and argumentation effectively in science classrooms. Henece, they may lack the ability to differentiate data from evidence, analyze data properly, and transform it into justified, well-communicated arguments (National Research Council, 2012). Consequently, students tend to only consider data that supports their own ideas, leading to improper generalizations and decisions. Teachers can help students overcome these challenges by supporting them in engaging in scientific discourse and argumentation (Jonassen & Kim, 2010; Henderson et al., 2018). This can provide a foundation for collaborative debate and argument (Baker et al., 2008; Golanics & Nussbaum, 2008; Topcu et al., 2010), which in turn fosters collaborative reasoning, dialogic interaction, and the ability to defend views using valid evidence or counterarguments (Kalypso & Costas, 2013).

Accordingly, it is the responsibility of curriculum developers and teachers to ensure that students acquire the necessary abilities related to discourse and argumentation in science (McNeill & Krajcik, 2007). A teacher's role is centered on guiding students to improve their argumentation skills by organizing argumentative discourse in the science classroom (McNeill et al., 2007). For this, teachers must have a solid grasp of argumentation knowledge and skills, and be able to create effective approaches to successfully implement argumentation in their science teaching. Skilled teachers can help students engage in scientific argumentation (Henderson et al., 2018; Jonassen & Kim, 2010) by designing problem-based or inquiry-based learning environments (Iordanou et al., 2019; Osborne et al., 2019), incorporating socio-scientific issues, providing clear information on scientific argumentation, and encouraging students to generate controversial questions.

When students are taught through argument-based evidence, they can conduct scientific experiments, engage in the process of developing hypotheses, design experiments, test hypotheses, and draw conclusions. For example, in a science classroom, students may be tasked with an assignment to design an experiment to test the effects of different fertilizers on specific plant growth. Students would first search the topic, develop a hypothesis (build an argument), and propose an experiment with appropriate controls and variables. When conducting the experiment, students would carefully observe and record data that enhances nature of their science skills. Then, when analyzing the results, they would provide proof (evidence-based arguments) to support their conclusions, such as comparing growth rates and calculating statistical significance. By engaging in this process of argumentation and evidence-based reasoning, students can actively build their understanding of the scientific method and develop reasoning skills essential for scientific literacy. Constructing coherent, evidence-backed arguments is a key component of scientific practice that science education should aim to cultivate.

Another example that illustrates argument-based evidence begins with the following question: Should we eat fast food? Students might form the following claim: Eating fast food can be unhealthy for our health. To support that claim, a student must present reliable evidence, such as a study from authentic resources. For instance, a study conducted by Bowman et al. (2004) found that when

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children in the United States consume fast food, it could potentially increase their risk of developing obesity. The reasoning connects the evidence to the claim, explaining why the evidence supports the claim. The relationship among claim, evidence, and reasoning can also be illustrated by the association between obesity and osteoarthritis. The claim could be that obesity is associated with knee osteoarthritis. To support this claim, students might search for articles that back up the claim, such as Khan et al. (2020), who concluded that obesity is significantly associated with osteoarthritis and that obese individuals (BMI ≥ 25 kg/m2) are at high risk of disease development. The reasoning connects the evidence to the claim that obesity is linked to knee osteoarthritis due to increased mechanical stress on joints, chronic inflammation from adipose tissue, and altered biomechanics. Excess weight accelerates cartilage wear, leading to joint degeneration and osteoarthritis progression. The examples demonstrate how students can improve their understanding of the nature of science (NOS) by supporting their arguments with experiential evidence, which provides insight into how scientific knowledge is produced. Additionally, the second and third examples enhance students' research abilities, such as finding relevant information, conducting critical analysis, and problem-solving. In short, the claim typically answers the question "What does the student think?" while the evidence typically answers the question "How does the student know what they know?" and the reasoning answers the question "How does the student think?"

The examples discussed above demonstrate the importance of fostering argumentation and scientific discourse in science education. To effectively implement argument-based evidence lessons, science teachers need to develop specialized skills and pedagogical strategies. This approach is essential for cultivating students' scientific literacy and reasoning abilities, which are critical for their understanding of the scientific method and engagement in the practices of the scientific community.

Regarding these skills, Andrée and Viiri (2018) and Alfarraj et al. (2023) found that pre-service elementary school teachers were not aware of the components and skills required for scientific argumentation and were not inclined to implement these skills in their teaching. These studies showed that pre-service elementary teachers need different levels of skills to analyze, evaluate, recognize, and assess evidence and justification in argumentation. Similarly, Romano et al. (2017) investigated in-service high school science teachers' understanding of argumentation and found that teachers preferred to use evidence to support their own perspectives rather than to engage students in discussing different viewpoints. However, the teachers did acknowledge the importance of argumentation for students' learning and thinking (Perdana et al., 2019). These studies indicate that both pre-service and in-service teachers lack the necessary skills and awareness to effectively implement discourse and argumentation in science classrooms.

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Several studies have examined the use of scientific argumentation and discourse practices by scientists across various domains, including discoveries, knowledge and theory building, information organization, claim negotiation, and observation interpretation in fields such as science, chemistry, biochemistry, biology, biomedical engineering, physics, nanoscience, and engineering. However, limited studies have conducted systematic reviews of research on argumentation and scientific discourse to explore crucial aspects for researchers and practitioners. Erduran et al. (2015) reviewed argumentation research in science education from 1998 to 2014 and demonstrated that previous studies focused more on linguistic perspectives and emphasized discourse, discussion, and

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talk over other related concepts such as conversation, dialogue, and negotiation. The authors also noted variations in the coverage of reasoning, evidence, and inquiry. To address this research gap, the current study aimed to conduct a descriptive trend analysis of research articles on argumentation and related concepts published in ESERA conference proceedings from 2011 to 2021, examining keywords, focus, methodology, and common instruments used.

The analysis of previous research studies through content analysis of published articles in high-ranking academic journals or well-respected conferences is an important aspect of educational research, as it can provide valuable insights into emerging trends and major themes in the literature (Li et al., 2020; Lin & Mintzes, 2010; Lin et al., 2014). To address the research gap in the area of argumentation and discourse, the authors first searched for relevant articles in academic journals, but found very few. Therefore, they decided to focus their analysis on research published in well-known conferences, such as the NARST and the ESERA. They ultimately selected ESERA as the source, as it publishes full papers or extended abstracts, and has a dedicated strand for Argumentation and Discourse in each of its proceedings. Consequently, the authors conducted a trend analysis of research articles on argumentation and related concepts published in ESERA conference proceedings from 2011 to 2021.

1.1. The purpose of the Research

This study explored and analyzed research related to argumentation and discourse presented and published in ESERA conference proceedings from 2011 to 2021. It answered the following main and sub-questions:

Main Question:

What are the trends and characteristics of research related to argumentation and discourse presented and published in ESERA conference proceedings from 2011 to 2021?

Sub-questions:

1. What are the percentages of articles related to argumentation and discourse published in ESERA proceedings from 2011 to 2021?
2. What are the trend-related keywords published in ESERA proceedings from 2011 to 2021?
3. What are the goals and focus of the research on argumentation in science education published in ESERA proceedings from 2011 to 2021?
4. What are the most common methodologies used in argumentation research in science education published in ESERA proceedings from 2011 to 2021?
5. What are the most common instruments used in argumentation research in science education published in ESERA proceedings from 2011 to 2021?

2. Method

2.1. Procedures

In this research the qualitative approach using the document analysis to collect the data required for answering the research questions since qualitative research methodologies primarily leverage textual and visual data (Creswell, 2014) . The process adhered to the review methods outlined by the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) for systematic reviews of educational research literature, as established by Bennett et al. in 2005. The review encompassed the following three primary phases, as follows:

First, the process of selecting research papers pertaining to argumentation for analysis involved establishing specific criteria for inclusion or exclusion in the review. Through electronic database searches, studies meeting these criteria were identified and listed. Subsequently, the abstracts of these studies were screened to ascertain whether they fulfilled the inclusion criteria.

Second, the criteria for the analyzing research articles related to discourse and argumentation that were selected for analysis were reviewed in terms of the goal of focus, methodology, and common instruments used in argumentation. Subsequently, among all related articles published in

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the ESERA proceedings from 2011 to 2021 (1,607 in total), those that were identified as related to argumentation and discourse were those that were included in the 7th strand of each proceeding (81 in total), comprising 5.1% of the total articles presented in all targeted proceedings. The ESERA conference proceedings were selected for examination in this study because they address crucial research aspects of research in science education and focus on essential, and cutting-edg topics topics. The conference organizers asserted that the important goal of the conferences is to aid in building a sustainable future for learners by emphasizing emphasis on highly relevant aspects and showing the desire to focus on different approaches that would enhance knowledge-related aspects of science education research and practice, including learning processes and the context of instruction. In addition, the authors' guidelines set by the conference organization committee instruct researchers to reflect on the most modern approaches to subjects related to science education. The International Scientific Committee of the conferences suggests several themes for each conference, one is specified for Discourse and Argumentation in Science Education. Researchers from worldwide participate in ESERA proceedings by sharing their thoughts and experiences and gaining new knowledge about issues related to science education, including argumentation and discourse. This may enable them to participate in the improvement of science education in their own countries. Papers submitted to ESERA conferences are subject to strict revision processes and reviewed by two referees. This means that analyzing research papers from ESERA conference proceedings would add fruitful information and new ideas related to argumentation and discourse, assisting researchers and educators in their efforts toward science curriculum reform. Furthermore, we choose ESERA because most of the abstracts presented in its proceedings might be published as full papers in several well-known journals.

Third, reviews of research articles related to argumentation and discourse published at ESERA conference proceedings have not been addressed in all studies related to research trends. Accordingly, the present study aimed to perform a trend analysis of research presented at the ESERA conference proceedings from 2011 to 2021 to determine the trends in important aspects of argumentation and discourse.

Fourth, not all studies related to research trends have addressed reviews of research articles on argumentation and discourse published in the ESERA conference proceedings. Accordingly, the present study aimed to perform a trend analysis of research presented at the ESERA conference proceedings from 2011 to 2021 to detect trends in the important aspects of argumentation and discourse as well as educational research methodologies.

2.2. Sample

The researchers identified the articles related to argumentation from all ESERA proceedings, as those articles were included in a strand called "Discourse and Argumentation in Science Education", which were specified by the conference organizers in all proceedings published between 2011 and 2021 (ESERA, n.d.). In total, 81 articles were included in those strands. These articles were analyzed to determine the trends in the aspects of key words, subject of focus, and instruments used by the researchers. The distribution of research articles included in the argumentation and discourse strand as compared to all strands over the targeted years is presented in Table 1, which shows that argumentation and discourse articles represent 5.1% of the targeted ESERA proceedings articles.

2.3. Instrument

The study developed its tool for this trend analysis guided by similar studies such as Bennett et al. (2005), whose review methods included the following four main phases:

1. Searching and screening: Developing criteria for including or excluding studies in the review, searching through electronic databases to find studies that meet the established criteria, and then evaluating the identified studies to determine if they meet the inclusion criteria.
2. In-depth review and data-extraction: Summarizing and evaluating the contents of studies according to pre-determined categories.

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3. Synthesis: Providing an overview of the quality and relevance of the studies included in the in-depth review and compiling and weighing the collective findings from the studies.

This study tool included the following five components: argumentation and discourse related keywords; goals of argumentation and discourse studies; methodologies employed in argumentation and discourse research studies, and; tools and instruments used in argumentation and discourse research studies

In this study, a descriptive type of systematic content analysis was used to explore the trends and important issues in a research related to argumentation in science education (Jayarajah et al., 2014; Lin et al., 2014). The researchers organized the initial version of the analysis tool, which consisted of six parts: research approach, purpose of the research, type of data collected, types of tools used, types of research samples, and number of researchers for each paper. The strand's theme was specified by the conference organizers, whereas the other themes were identified theme was specified by the conference organizers papers and choosing one of the categories specified by the tool. This involved reading or scanning the whole study, especially the research methodology, to understand the research approach and then selecting one of the four options or an option for no data if the research approach or type could not be determined. The tool clearly defines each theme and each part of each of the themes. The first version of the tool was sent to specialized expert professors from the department of science education. The experts' comments and suggestions resulted in the final version of the tool, which consisted of five parts: 1) articles related to argumentation and discourse; 2) trend-related keywords and sub-keywords; 3) goals of focuses of the published research; 4) methodologies employed in argumentation and discourse research studies; and 5) tools used in argumentation and discourse research studies presented in ESERA.

2.4. Validity and Reliability

To validate the analytical tool, it was reviewed by certified experts in curriculum and instructio. These experts had extensive knowledge of contemporary research trends in science education. Based on their feedback, the tool was improved, particularly by addressing language-related issues across multiple sections. The refined tool was then organized into eight distinct categories: distribution of all ESERA articles and argumentation and discourse articles over specific years, keywords in the titles/keyword sections/abstracts, the goals and focuses of the published research, research methodologies, and research instruments and tools.

To verify the reliability of the analysis, the researchers randomly chose 20 articles, which made up around 25% of the total research articles they examined. Subject matter experts in science education and related research independently analyzed the 25% sample, each coding a subset of the articles. The researchers then calculated the inter-rater reliability using the kappa coefficient, and the results ranged from 0.80 to 0.93, indicating substantial to almost perfect agreement among the raters (Landis & Koch, 1977).

3. Research Findings

3.1. The Percentages of Articles Related to Argumentation and Discourse Presented in ESERA Proceedings from 2011 to 2021

Table 1 shows an analysis of sequential trends in papers on argumentation within the span of 10 years covered, indicating that out of the 1,594 papers from all six proceedings, 81 (5.10%) addressed the topic of argumentation and discourse. The data demonstrates that the volume of argumentation research within the ESERA proceedings over the ten-year period did not follow a consistent upward or downward trajectory. Instead, the number of papers related to argumentation fluctuated irregularly, initially declining between 2011 and 2013, then remaining almost steady from 2013 to 2015, and rising once more from 2015 to 2017. The highest proportion of these articles (6.6%) was recorded in 2017.

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Table 1. *Distribution of all ESERA articles and argumentation and discourse articles over the specific years.*

Year	2011	2013	2015	2017	2019	2021	Total
No. of all strands in each proceeding	14	16	19	18	18	17	102
No. of all articles	303	322	326	243	238	162	1594
No. of articles in the argumentation and discourse strand	18	15	15	16	9	8	81
% of argumentation and discourse articles	5.9	4.7	4.6	6.6	3.8	5.00	5.1

3.2. Trend-Related Keywords and Sub-Keywords

Table 2 presents the distribution of research items across seven domains in science education over a 10-year period from 2011 to 2021. The domain with the highest concentration of items was Context and Content, comprising 32.58% of the total, followed by Thinking Skills and Learning Processes at 22.85%. Classroom Interactions and Discourse, Argumentation, and Specific Subject Areas comprised considerable portions as well, whereas Evaluation and Assessment and Systemic and Cultural Aspects represented smaller areas of focus. The total number of items across all domains is 267, indicating the breadth of research conducted in the field of science education during this time frame.

Table 2. *Keywords in the titles, the keyword section, and the abstracts.*

Domain	2011	2013	2015	2017	2019	2021	Total	%
Classroom Interactions and Discourse	15	9	4	4	5	4	41	15.36
Context and Content	26	17	16	13	8	7	87	32.58
Argumentation	10	7	9	10	2	2	40	14.98
Thinking Skills and Learning Processes	8	7	20	12	8	6	61	22.85
Specific Subject Areas	7	4	2	1	3	2	19	7.12
Evaluation and Assessment	3	1	0	1	0	1	6	2.25
Systemic and Cultural Aspects	3	2	5	3	0	0	13	4.87
Total	74	47	56	44	26	22	267	100

The keywords mentioned in the abstracts are illustrated in Fig 1. The seven most frequently occurring keywords are argumentation and science, which both appeared 29 times (10.9% each), followed by education (26 instances, 9.7%), discourse (21 instances, 7.9%), learning (16 instances, 5.0%), classroom (13 instances, 4.9%), and scientific (12 instances, 4.5%). These top keywords indicate a focus on argumentation, science, education, discourse, and learning in the classroom and scientific contexts within the research presented in the abstracts published in ESERA proceedings through 2011-2021.

Figure (1) Word cloud for keywords.

Figure 2. Word cloud for kywords.

3.3. Identifying the Goals of Focuses of the Published Research

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Following a comprehensive process of coding and categorization, five distinct sets of research paper topics were published in the ESERA conference proceedings. Table 3 highlights the primary focus of researchers on the subject of argumentation and discourse, which are investigating discourse analysis and argumentation, exploring student learning and understanding, analyzing task features and student arguments; exploring the history of science and science textbooks; and analyzing multimodal discourse in science education.

Table 3. *Research goals of argumentation and discourse studies.*

	Domain	2011		2013		2015		2017		2019		2021		Total	
		#	%	#	%	#	%	#	%	#	%	#	%	#	%
1.	Investigating discourse analysis and argumentation	6	35	4	26.7	5	33.33	5	31.2	3	33.3	3	37.5	26	32.1
2.	Exploring Student learning and understanding	4	24	3	20	7	46.67	5	31.2	3	33.3	3	37.50	25	30.8
3.	Analysis of task features and student arguments	2	12	3	20.	2	13.33	1	6.2	2	22.2	1	12.50	11	13.6
4.	Exploring history of science and science textbooks	3	18	2	13.	0	0.00	1	6.2	0	0.00	0	0.00	6	7.4
5.	Analysis of multimodal discourse in science education	3	18	3	20	1	6.67	2	12.5	0	0.00	1	12.50	10	12.4
	Total	18	100%	15	100%	15	100%	16	100%	9	100%	8	100%	81	100%

Most studies in this collection focused on investigating discourse analysis and argumentation in science education and exploring student learning and understanding of scientific concepts. Around a third of the studies fall into each of these two broad categories, highlighting the central role that argumentation, discourse, and student conceptual understanding in science education research. Analysis of task features and student arguments, and exploration of the history of science and science textbooks received less attention, accounting for approximately 13.6% and 7% of the studies, respectively. Finally, the analysis of multimodal discourse in science education comprised approximately 12% of the research. Overall, the field consistently emphasizes understanding how students engage in scientific argumentation and discourse and how this relates to their learning and mastery of key scientific ideas and principles. Figure 2 provides an overview of the distribution of studies related to argumentation and discourse in science education across different years and focus areas. It demonstrates that the majority of the five identified focus areas - investigating discourse analysis and argumentation, exploring student learning and understanding, analyzing task features and student arguments, exploring the history of science and science textbooks, and analyzing multimodal discourse - are represented in each year from 2011 to 2021 even though the relative emphasis on these different focus areas varies over time.

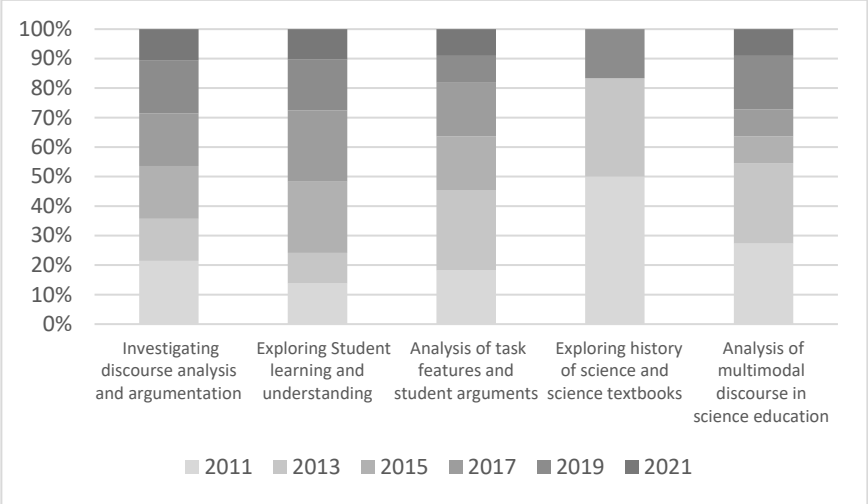

Figure 3. The nature of the trends of the goals of articles related to argumentation and discourse.

Figure 2: The nature of the trends of the goals of articles related to argumentation and discourse.

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3.4. Research Methodologies

As shown in Table 4, the methodological trends from 2011 to 2021 demonstrate a clear preference for qualitative research, which consistently accounted for the majority of the studies, ranging from 62.5% to 88.89% of the total.

Table 4. *Methodologies employed in argumentation and discourse research studies.*

Methodology	2011		2013		2015		2017		2019		2021		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Quantitative	0	0	1	6.67	2	13.33	5	31.25	1	11.11	2	25	11	13.58
Qualitative	15	83.33	13	86.67	12	80	10	62.5	8	88.89	5	62.5	63	77.78
Mixed- Methods	3	16.67	1	6.67	1	6.67	1	6.25	0	0	1	12.5	7	8.6
Total	18	100	15	100	15	100	16	100	9	100	8	100	81	100

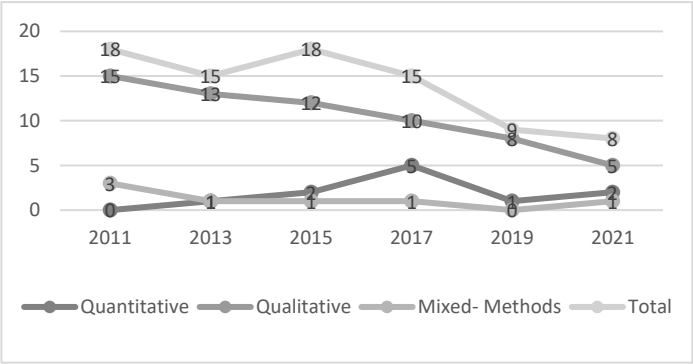

Figure 4. Line visualization of the distribution of the research methods over the years.

3.5. Research Instruments

The data reveals that document and transcript analysis was the most extensively utilized research instrument, accounting for 41.84% of the total instruments used between 2011 and 2021. Case studies are the second most frequently employed method, comprising 17.35% of the total. Surveys and questionnaires (13.27%), observation (12.24%), and in-depth interviews and focus groups (10.20%) also featured prominently, indicating a mix of quantitative and qualitative approaches. Tests are the least common instrument, comprising only 5.10% of the total even though the overall usage of instruments fluctuated over the years

Table 5. *Instruments used in argumentation and discourse research studies presented in ESERA.*

Instruments	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**Total**	
Surveys and questionnaires	2	0	2	6	1	2	13	13.27%
Tests	1	2	0	1	0	1	5	5.10%
In-depth interviews and focus groups	1	2	2	3	1	1	10	10.20%
Observation	5	0	2	1	4	0	12	12.24%
Case study	1	3	3	5	2	3	17	17.35%
Document and transcript analysis	10	9	14	4	1	3	41	41.84%
Total	20	16	23	20	9	10	98	100.00

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4. Discussion

This investigation examined scholarly works presented at the ESERA conferences from 2011 to 2021, aiming to determine trends in scientific argumentation and discourse research. These psychological and educational principles are crucial, as they align with the essential abilities and expertise that students will need in their future professional endeavors. Early analyses revealed that 5.1% of the papers centered on argumentation and discourse, which is highly relevant because such practices are integral to the NGSS. Additionally, the data showed that the bulk of the publications occurred between 2011 and 2017, a surge possibly linked to the emergence of *A Framework for K-12 Science Education* (NRC, 2011), which laid the groundwork for the NGSS. Erduran et al. (2015) conducted a journal content analysis from 1998–2014 on research trends related to argumentation in science education. They found that the distribution of argumentation-related research articles across the journals *Science Education* (SE), *International Journal of Science Education* (IJSE), and the *Journal of Research in Science Teaching* (JRST) ranged between 4.7% to 5.7%, with an average of approximately 5.0% over the time period analyzed. These findings suggest there has been a significant and continuing level of scholarly interest and focus on the role of argumentation and scientific discourse in science education.

The most commonly recurring terms across all the papers included argumentation, science education, discourse, learning, classroom, and scientific. Such terms and concepts are critical for science curricula and teacher preparation programs as well as science teacher professional development programs. In our study, we employed a technique to determine keywords as words found in association with other key terms within the same texts. The aggregation of keywords into clusters is crucial because it captures the essence of the main ideas. This suggests that the scholarly community is deeply engaged in exploring the implications and pedagogical applications of argumentation and discourse in science education, as they are correlated with thinking skills. For example, Hasnunidah et al. (2020) found that argumentation and critical thinking skills contributed to enhancing students' grasp of fundamental concepts in biology.

The thematic coding and categorizing of goals and subjects targeted by studies related to argumentation and discourse published in ESERA conferences proceedings from 2011 to 2021 resulted in five groups as shown in Table 3. Several sets of goals for discourse and argumentation research were identified in the analyzed literature. The most recurring set was the studies focusing on investigating discourse analysis and argumentation and exploring student learning and understanding, whereas the least recurring was studies that investigated exploring the history of science and science textbooks and analyzed multimodal discourse in science education. The fact that the majority the articles address either the investigation of discourse analysis and argumentation or the exploration of student learning and understanding is a particularly encouraging sign. It demonstrates a concerted effort to build a comprehensive understanding of the cognitive, social, and pedagogical aspects of these crucial academic skills and processes. Studies have found that argumentation can help students acquire the ability to achieve conceptual understanding (Asterhan & Schwarz, 2007; Nussbaum & Sinatra, 2003). Other studies have concentrated on exploring whether the quality of peer-to-peer dialogue and group work affects students' gains in discourse and argumentation skills (**Asterhan & Schwarz, 2007, 2009; Rapanta et al., 2021**) and conceptual understanding in several domains (De Lima et al., 2010). Additional research (Ghebru & Ogunniyi, 2017; Özdem et al., 2013; Sampson et al., 2011; Sampson & Clark, 2009; Sampson et al., 2013) has concentrated on in-service and pre-service science teachers' beliefs and understanding of discourse and argumentation as well as argumentation skills (Venville & Dawson, 2012; Xie & So, 2012). However, most of these studies have focused on the description of such goals as teachers' beliefs, attitudes, perspectives, and skills. Some other studies have targeted the analysis of discourse or students' engagement in argumentation (Lauscher et al., 2018; Minogue et al., 2010; Van Dijk, 1993).

The results for the third section indicate that qualitative research methodologies were dominant. The preponderance of qualitative studies suggests a thoughtful and precise approach to this subject matter. The reliance on in-depth analysis of documents, transcripts, and case studies allows researchers to capture the complexity and context-dependent nature of argumentation and discourse,

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which is essential for developing a rich and meaningful understanding of these phenomena. Aldahmash et al. (2019), in *Research Trends in In-Service Science Teacher Professional Development from 2012 to 2016*, found that most of the studies published from 2012 to 2016 were qualitative in nature. Many qualitative research articles have targeted the analysis of written documents for argumentation or discourse (Berland & Lee, 2012; Berland & Reiser, 2009; Chang & Chiu, 2008; Lauscher et al., 2018; Simon 3t al., 2006; Tagninet et al., 2017; Zembal-Saul, 2009). Some of these studies have resulted in the development of instruments like "ArguminSci," developed by Lauscher et al. (2018) for the analysis of documents to identify the components of argumentation, suggesting the importance of implementing a qualitative approach when conducting studies focused on argumentation.

The last part covered the research instruments used by researchers who studied discourse and argumentation. Document and transcript analysis, as well as case studies, were the most commonly used methods in argumentation and discourse research studies presented at ESERA from 2011 to 2021. These analysis tools were used alongside other instruments such as observation, open-ended questionnaires, and interviews. This finding is consistent with the conclusions of Aldahmash et al. (2019) in their study "Research Trends in In-Service Science Teacher Professional Development from 2012 to 2016," which found that qualitative instruments constituted almost two-thirds of the research tools used. The analysis targeted textbooks, written argumentations, and oral discourse and argumentations. Most of the studies used such instruments to collect mostly qualitative data and information, as indicated in the fifth part of the results (Ramage, Bean, & Johnson, 2016; Tagnin, Ní Ríordáin, & Fleming, 2017). The findings also concluded that document and transcript analysis, case studies, and surveys and questionnaires were the most common methods of data collection.

This review of the ESERA conference proceedings from 2011 to 2021 reveals a diverse range of topics concerning argumentation and discourse. The research focused on various aspects including students' conceptions, skills, beliefs, and the argumentation skills of in-service science teachers. The predominant methodologies employed in argumentation research within science education were qualitative. The primary tools used for data collection were document and transcript analysis, observation, and interviews. These findings suggest that discourse and argumentation research aims to acquire profound and deep knowledge that can contribute to the advancement of science education as a whole, with a specific emphasis on science teaching and learning. The focus in education has shifted towards enhancing students' argumentation skills. For example, the framework for the PISA 2025 Science Assessment includes three key competencies, one of which concentrates on developing students' abilities to design and evaluate scientific investigations, as well as to critically interpret scientific data and evidence [OCED, 2023]. Additionally, the TIMSS 2023 assessment evaluates a variety of science practices in the context of its science content objectives and cognitive domains, including the ability to make arguments based on evidence [80]

5. Conclusions and Implications

The purpose of this study was to identify scientific argumentation and discourse research trends in keywords, objectives, instruments, and methodologies. A qualitative content analysis was used to discern trends in ESERA argumentation and discourse. The largest proportion of argumentation and discourse articles was published in 2017. These publications focused on students' concepts, beliefs, and the argumentation skills of in-service science instructors. However, keywords did not follow a consistent pattern in the ESERA conference proceedings articles on argumentation and discourse from 2011 to 2021. Qualitative research methods were predominant. The most common data collection methods were document and transcript analyses. Research in discourse and argumentation has become increasingly important because of its connection with the Next Generation Science Standards (NGSS), which emphasize scientific and engineering practices, especially evidence-based argumentation. Hence, teachers must be trained to prioritize discourse and argumentation in their teaching and cultivate believe in the role of these practices in developing students' problem-solving abilities for the future. Teachers play a crucial role in equipping students with the skills and opportunities to engage in scientific argumentation, to construct arguments, and to participate in productive discussions that support and challenge their claims with evidence. Furthermore,

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argumentation, discourse, and dialogue have the potential to enhance students' abilities to construct explanations, models, and theories. They also help students use warrants and backings to connect evidence to claims, fostering a meaningful understanding of science concepts and successful implementation of scientific processes. Based on the results of this study, a qualitative analysis of papers focusing on argumentation could generate more comprehensive findings, discussions, and trends, providing further insights into the effectiveness of scientific argumentation in science education. Investigating trends in research related to argumentation and discourse in well-known Middle Eastern journals and conferences is suggested for further study to gain insights into the extent to which these journals target argumentation and discourse.

Ethical statements

- This research is a review study that did not include human subjects and, therefore, did not require ethical approval from the ethical community at the University
- Informed consent was obtained from all individual participants included in the study.

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