Argumentation in K-12 Mathematics and Science Education: A Content Analysis of Articles

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Article Info	Abstract
	The current study employed a content analysis approach to analyze and compare argumentation research in K-12 mathematics and science education published on top five academic journals with the highest impact factor from 2010 to 2019. It includes 9 research articles in the field of mathematics education and 77 research articles in the field of science education. The objectives of this study are to examine the similarities and differences in number of articles, contributors by nationality, method and design, subject, model, setting, and research topics. The results show that despite the argumentation research trend in both contexts tends to decrease, there are more researches related to argumentation on science subject compared to mathematics at K-12 level. These results have an impact on the increasingly diverse categories of argumentation studies in K-12 science. The implications of this research can obviously provide insights to the study of argumentation for mathematics education, science, and education researchers.

Introduction

Argumentation is nothing new to any of the great thinkers of human history, including Plato and Aristotle (Erduran, Ardac, & Yakmaci-Guzel, 2006), they were engaged in argumentation and regarded as the centerpiece of knowledge construction (Metaxas, Potari, & Zachariades, 2016). Meanwhile, research on argumentation studies has been predominantly examined in the early 20th century. During that century, argumentation was seen, for the most part, as a product of reasoning (Mercier & Sperber, 2011; Zarefsky, 2005). From this point of view, reasoning and argumentation as the foundation of justifiarton for a pedagogical teaching paradigm focused on logical inferences (Rapanta, 2018).

Today, argumentation is emphasized by many researchers as one of the most important activities and it has been an interesting field to investigate. In education, argumentation is not only an ability that needs to be mastered but also because it can be used to promote learning in philosophy, history, science, mathematics, and many other fields (Mirza & Perret-Clermont, 2009; Noroozi & Hatami, 2019). In the field of science education, argumentation can lead not only to the learning and the advancement of science but also to the creation of argumentative skills (Martins & Justi, 2019). Argumentation is also a central component of the scientific process (Mathis et al., 2017) and an essential competency for science literacy (Lin & Hung, 2016). In addition, argumentation has played an essential role in the curriculum to develop scientific and critical thinking of

students, with an increasing number of publications over the past three decades, focused on analyzing the argumentative discourse in the context of science learning (Henderson et al., 2018; Jiménez-Aleixandre & Erduran, 2008).

In the field of mathematics education, argumentation ability becomes important in mathematics teaching and learning processes (Hidayat, Wahyudin, & Prabawanto, 2018). These skills are required for individuals to be able to engage in relatively open-ended mathematical discussions that are normally guided by mostly formal rules and deductive approaches (Vogel et al., 2016). Argumentation as a kind of classroom discourse is useful for developing mathematical knowledge that takes place in classroom conversations and can facilitate the development of learners' knowledge of subject matter (Uygun & Akyuz, 2019). Knowledge in argumentation is also important for logical comprehension and effective communication (Lin, 2018). Moreover, argumentation in mathematics is an essential part of the mathematics discipline and a key indicator of mathematical competence (Graham & Lesseig, 2018). In the process of building arguments and criticizing others' reasoning, students develop their understanding of underlying mathematical ideas and engage in critical thinking activities (Graham & Lesseig, 2018; Yackel & Hanna, 2003).

Furthermore, argumentation is one of the skills that has been a prominent interest in K-12 education (Schwarz, 2009) in which students are expected to engage in learning. Learning the argumentation process assists the development of skills in reasoning, critical thinking, communication, social behaviors, and gathering information. These skills are necessary for everyday life, professional activities, and all aspects of education (Mathis et al., 2017). Being familiar with argumentation skills allows a person to understand the perspectives of others, evaluate the adequacy or necessity of existing warrants, and assess the validity of common assertions (Lin & Mintzes, 2010).

According to research in international perspective, in the field of science education, numerous research studies focused on the description of argumentation and the empirical investigation of the argumentation structure or the advancement of argumentative skills in science lessons in schools (Heitmann et al., 2014), whereas the reforms of the curriculum in mathematics education have given rise to an emerging research program on teaching and learning argumentation at various grade levels (Lin, 2018). Particularly, Argumentation at primary and secondary schools has been extensively discussed as a significant way to facilitate learning through the development of social and cognitive processes (Dovigo, 2016). These evidences indicate that argumentation has become a crucial research topic in the field of K-12 mathematics and science education.

There are a number of research articles focused on argumentation in mathematics and science education which have been documented and published on high impact academic journals. In particular, some researchers have used these articles as a data for conducting research through content analysis. For example, Erduran, Ozdem, & Park (2015) presented, by content analysis, a study of work on argumentation in science education focused on publications in three academic educational journals from 1998 to 2014. Despite there are some study concerning research trends in argumentation in science education, very little is known about the comparison of research trends in argumentation studies between K-12 mathematics and science education. Therefore, this research can

be obviously important provided the groundwork to the study of argumentation for mathematics and science education researches through referable insight.

As having been previously mentioned, in order to broaden basis of the knowledge about the advanced development of argumentation studies, the purpose of the study is to compare the current state of argumentation research trends published on top five referred journals in the field of mathematics and science education over the last decade from 2010 to 2019 through article content analysis. To this end, the following research questions are addressed:

1. What are the diverse in nationalities that represent contributors according to number of articles published in journals of mathematics education and science education?
2. What grade level are selected as research subjects in argumentation studies both in journals of mathematics education and science education?
3. What research methods, design, and model have been used for argumentation studies?
4. What are the research settings and topics for the study of argumentation that has been applied in K-12 mathematics and science education?

Method

In this study, content analysis was used to study empirical documentation on academic journals with the aim of grouping similar cases or data according to certain concepts and themes as well as systematically organizing and interpreting the data (Bozkurt et al., 2015). For manageable content categories, we adapted the methodology used by Ryve (2011) which has two main research procedures as follows.

The Process of Selecting Articles

We have chosen to focus this study on articles published in the top five research journals in the field of mathematics education and science education with the following criteria: (1) indexing in Scopus; (2) first quartile; and (3) the highest impact factor. For current, transparent, and comprehensive citations, the citation score metric from SJR 2019 was used in this study. Table 1 presents the journals included in this analysis. In searching for articles that focus on argumentation research, we decided to include articles that use the words argumentation, argument, or argumentative in the title, abstract, or keyword. The justification for this approach is to include papers where the argumentation is the core concept. To find the articles, we use web search functions from each journal. Our search covers all article volumes from 2010 to 2019.

Analytical Questions and Guidelines for Categorizing

Four research issues mentioned earlier have been proposed. This study focuses on seven research categories: (a) number of research, (b) author's geographical affiliation, (c) research subject, (d) research method and design, (e) research model, (f) research theme, and (g) research topic. Frequencies were calculated for the respective categories.

Table 1. International Research Journal Included in the Analysis

Journal Domain	No	Journal Name	Publisher	Quartile	Impact Factor*
Mathematics Education	1	Journal for Research in Mathematics Education	NCTM	Q1	2.916
	2	Educational Studies in Mathematics	Springer	Q1	1.574
	3	Mathematical Thinking and Learning	Taylor & Francis	Q1	1.569
	4	ZDM-International Journal on Mathematics Education	Springer	Q1	1.082
	5	Mathematics Education Research Journal	Springer	Q1	0.817
Science Education	1	Journal of Research in Science Teaching	John Wiley & Sons	Q1	3.012
	2	Studies in Science Education	Taylor & Francis	Q1	2.319
	3	Science Education	John Wiley & Sons	Q1	2.012
	4	International Journal of Science Education	Taylor & Francis	Q1	1.058
	5	Research in Science Education	Springer	Q1	0.893

Note. *2019 journal impact factor from Scimagojr

Results and Discussion

Number of Research

In total, 86 articles were analyzed where 9 of them were from journals in the field of mathematics education, and the rest 77 were from journals in the field of science education. Table 2 presents frequency by domain journals and year of the articles.

Table 2. Frequency of Articles Based on The Domain of Journals and Years

Years	K-12 Mathematics Freq.	K-12 Science Freq.
2010	-	12[a]
2011	-	7
2012	1	11[b]
2013	1	10
2014	3[a]	9
2015	1	9
2016	1	6
2017	1	5
2018	-	4
2019	1	4
TOTAL	9	77

Note. [a]first highest frequency, [b]second highest frequency.

As shown in Figure 1, the frequency of articles by the year suggests that, over time, there has been a decreasing interest in argumentation research both in K-12 mathematics and science education. However, the number of argumentation articles in the field of K-12 science education is gradually higher than in the field of K-12 mathematics education. Overall, 77 out of 86 argumentation articles are in K-12 science contexts. The results of

this study are in line with Tekin, Aslan, & Yilmaz (2016) which states that argumentation has been remarkably relevant in the most cited science education studies over the last 15 years.
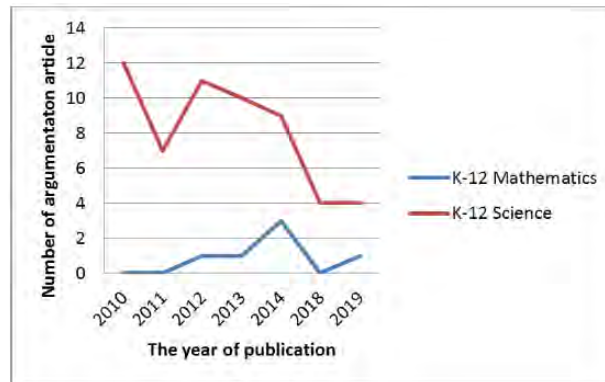

Figure 1. Distribution based on the total number of argumentation article

Geographical Contributor by Nationality

Table 3 shows a summary of geographical affiliation based on the contributors' correspondents for the study of argumentation according to the theme of the article.

Table 3. Frequency of Contributor Based on Nationality

Nationality	K-12 Mathematics	K-12 Science
	Freq.	*Freq.*
USA	5[a]	36[a]
Germany	2[b]	2
Netherlands	1	-
Australia	1	3
Singapure	-	1
Lebanon	-	2
Cyprus	-	3
Spain	-	2
United Kingdom	-	2
Taiwan	-	5[b]
Brazil	-	3
Malaysia	-	2
Lebanon	-	1
Chile	-	1
Denmark	-	2
South Africa	-	1
Turkey	-	2
Sweden	-	3
China	-	2
Israel	-	2
South Korea	-	2
TOTAL	9	77

Note. [a]first highest affiliation, [b]second highest affiliation.

The results show that most contributors both on K-12 science and mathematics research come from the US based on the author's correspondence. Taiwan (freq.= 5) is the second highest author affiliation in the context of K-12 science and the highest contributor to nationality in the Asia Pacific region. Germany (freq.= 2) is the second highest nationality contributor in the mathematical context in K-12. 6 countries have published at least one paper. Cultural diversity occurs in the sense of K-12 research because the affiliations of the first scholars come from many geographical regions. In each type of journal, several Middle Eastern and African researchers are involved in the study of argumentation. In comparison, very few Southeast Asian scholars (e.g., Indonesia, Thailand, and the Philippines) contributed their scientific research to the top five academic journals.

Research Subject

Information about the research subjects is listed in Table 4. K-12 The Indonesian education system was used in this study. The results show that the majority of science education researchers tend to analyze the argumentation activities of secondary school students. Junior secondary school students (freq.= 25) were the first highest research subjects in the context of K-12 science, while senior secondary school students (freq.= 22) were the second highest. For mathematics education researchers, elementary school students (freq.= 4) were the first highest target population, while junior secondary school students (freq.= 2) were the second highest. Kindergarten students are not the focus of study by researchers both in the field of mathematics education and science education. The term unknown is used for the category of no research participants such as theoretical studies, which are 2 in K-12 mathematics and 10 in K-12 science. In addition, several articles use more than one research subject simultaneously.

Tabel 4. Frequency of the Articles Based on Research Subject

Subject	Age	K-12 Mathematics	K-12 Science
		Freq.	*Freq.*
Kindergarten	5-6	-	-
Elementary school	7-12	4[a]	15
Junior secondary school	13-15	2[b]	25[a]
Senior secondary school	16-18	-	22[b]
Kindergarten+Elementary	5-12	1	-
Elementary+Junior secondary	7-15	-	1
Junior+Senior Secondary	13-18	-	2
Elementary+Junior+Senior Secondary	7-18	-	2
Unknown		2	10
TOTAL		9	77

Note. [a]first highest subject, [b]second highest subject.

Research Method and Design

The articles showed a distribution between four methods and sixteen research designs. All the papers were classified under the method according to the process and research design (Table 5).

Table 5. Frequency of the Articles Based on Research Methods and Design

Research Methods	Research Design	K-12 Mathematics Freq.	K-12 Science Freq.
Qualitative[*]	Literature review	1	3
	Theoritical article	1	7[a]
	Case study	-	4[b]
	Longitudinal study	1	-
	Cross-sectional study	-	1
	Socio-constructisism/ sociocultural activity	1	3
	Pre- and post-student interview, videotape, and student writing	-	1
	Framing for argumentation	-	2
	Subtotal	4	21
Quantitative	Teaching experiment	3[a]	22[a]
	Descriptive survey	-	3[b]
	Subtotal	3	25
Developmental	Instructional design	1	4[b]
	Learning design	-	3
	Design-based	1	3
	Task-based	-	4[b]
	Between-groups	-	9[a]
	Small-scale study/ pilot study	-	1
	Other	-	3
	Subtotal	2	27
Mixed method		-	4
TOTAL		9	77

Note. [*]the highest method, [a]first highest design, [b]second highest design.

The results show that qualitative-based articles are the highest weights of methods in both research contexts. 4 of studies were applied in K-12 mathematics and 27 of studies were applied in K-12 science. Mixed-methods are not popular research methods in argumentation studies. Particularly, teaching experiments are the most frequently used research design, of which 3 in K-12 mathematics context and 22 in K-12 science context. As can be seen from Table 5, the distribution of research designs in the context of K-12 science is more diverse than in the context of K-12 mathematics.

Research Model

The distribution of the articles according to the model for argumentation analysis is presented in Table 6. The results show that most of the articles use Toulmin's as a model for analyzing students' argumentation activities, both in the contexts of K-12 mathematics (freq.= 2) and in the contexts of K-12 science (freq.= 12). Students' views about explanation, argument, and evidence are also the first highest research model in K-12 science contexts. The frequencies of argumentation studies concerning the research models clearly vary within the contexts of K-12 science.

Table 6. Frequency of the Articles Based on Research Model

Model	K-12 Mathematics Freq.	K-12 Science Freq.
Toulmin's	2[a]	12[a]
Argumentation discourse analysis	1	10[b]
Toulmin's+Peirce's	1	-
Co-construction, integration, and modification argument	1	-
Diagrammatic and narrative argumentation	1	-
Argumentation-based inquiry	1	6
Mariotti's characterization	1	-
SEE-SEP model	-	1
Content analysis	-	2
Walton's ideas	-	1
Pragmatics analysis	-	2
Argumentation task in national assessment	-	1
Students' views of explanation, argument, and evidence	-	12[a]
Theoretical construct of framing	-	2
Construct arguments when working in group	-	4
Rasch analysis based on a partial credit model	-	1
Conceptual framework of communities	-	1
Cognitive think-aloud interviews	-	2
Pattern of reasoning and argumentation	-	1
Learning progression	-	1
Argument-Driven Inquiry	-	2
Argument-based interventions	-	1
Quality Talk Science, a professional development model and intervention	-	1
Social network analysis (SNA)	-	1
Framing uncertainty	-	1
Social- or individual-based online learning program	-	3
Pre- and post-tested using a questionnaire and interviews	-	2
Modelling-based teaching activities	-	2
Simon's framework	-	1
Unknown	1	4
TOTAL	9	77

Note. [a]first highest model, [b]second highest model.

Research Setting

Table 7 shows that most of argumentation studies both in K-12 mathematics (freq.= 6) and science context (freq.=19) use small-group interaction as research setting. Construction of a conjecture and proof (freq.= 2) is the second highest setting in K-12 mathematics contexts, while the test of argumentation tasks and Teachers' and students' discourse (freq.= 9) are the second highest setting in the contexts of K-12 science. In K-12 science contexts, the quantities of argumentation studies regarding the research setting were distinctly varied.

Table 7. Frequency of the Articles Based on Research Setting

Setting	K-12 Mathematics	K12 Science
	Freq.	*Freq.*
Small-group interaction	6[a]	19[a]
Construction of a conjecture and proof	2[b]	-
Laboratory-based study	-	5
Survey by questions to argumentation and NOS	-	3
Sosio-scientific issues	-	5
Test of argumentation tasks	-	9[b]
Clinical interview	-	4
Learning progression	-	1
Scientific argumentation	-	4
Argument-based interventions	-	4
Teachers' and students' discourse	-	9[b]
Science seminar	-	1
Critical components of argumentation in classroom	-	1
Online argumentation	-	5
Unknown	1	7
TOTAL	9	77

Note. [a]first highest setting, [b]second highest setting.

Research Topics

Table 8 summarizes the information regarding the research topic in argumentation studies. The results indicate that analyzing students' scientific argumentation (freq.= 13) is the first highest research trend in the context K-12 science, whereas argumentation in socioscientific issues (freq.= 12) is the second highest research topic. In the contexts K-12 mathematics, collective argumentation (freq.= 5) is the most highest research topic. Topics in argumentation research in the field of K-12 science are more diverse than in the field of K-12 mathematics. The

results also indicate that, overall, argumentation studies for K-12 mathematics students are less discussed as research topics.

Table 8. Frequency of the Articles Based on Research Topics

Topic	K-12 Mahematics	K-12 Science
	Freq.	*Freq.*
Collective argumentation	5[a]	7
Diagrammatic argumentation and narrative argumentation	1	-
Inductive and deductive argumentation	1	-
Example-based argument	1	-
Proof based teaching (PfBT)	1	-
Modelling-based teaching	-	1
Classroom-based argumentation	-	3
Explanation, argumentation, and evidence to construct arguments	-	1
Argumentation in socioscientific issues	-	12[b]
Science writing heuristic	-	3
Scientific argumentation	-	13[a]
Developing a framework	-	1
Learning in a community of practice	-	1
Framing for argumentation	-	1
Argument for an epistemic approach	-	1
Teaching and learning science as argument	-	1
Argument driven inquiry	-	6
Argumentative task	-	2
Web based learning	-	4
Science capital	-	1
Argumentative reasoning	-	2
Social network analysis	-	2
Online argumentation	-	3
Subject matter knowledge and argumentation pedagogy	-	4
Argumentative discourse	-	5
Laboratory-based task	-	2
Conceptual learning	-	1
TOTAL	9	77

Note. [a]first highest topic, [b]second highest topic.

Conclusion

This study focuses on the research articles of argumentation in K-12 mathematics compared to K-12 science contexts published on the top five academic journals from 2010 to 2019. The study shows that regardless of interest in argumentation research in both fields tends to decrease, the number of articles in the context of K-12 mathematics published in the top five journals is fewer than in the context of K-12 science. There are several possible explanations for this result.

Many scholars indicated that argumentation has been studied mostly in the context of various socio-scientific issues in recent years (e.g., climate change, global warming, genetically modified organisms) (Lin & Mintzes, 2010; Erduran et al., 2015). While, in the field of mathematics education, many scholars often associated argumentation with proof. Obviously, proof theory and theory of argumentation are quite different disciplines (Krabbe, 2013). Some theorists have expressly contended that proofs are not arguments: this is because proofs offer certainty, while arguments cannot (Dufour, 2013).

Argumentation research both in the context of K-12 mathematics and science is mostly carried out by American researchers. This is due to the fact that in the United States, both the Common Core State Standards for Mathematical Practice (CCSSMP) and the Next Generation Science Standards (NGSS) include standards for argumentation. The CCSSMP require that students "construct viable arguments and critique the reasoning of others" (National Governors Association Center, [NGAC], 2010), while NGSS (NRC, 2012) suggests that "engaging in argumentation from evidence about an explanation supports students' understanding of the reasons and empirical evidence for that explanation, demonstrating that science is a body of knowledge rooted in evidence".

In the Asia-Pacific region, Taiwanese researchers are the only ones who conduct most argumentation researches in the context of K-12 mathematics and science. The distribution of researchers' nationalities in the context of K-12 science is more diverse than in the context of K-12 mathematics. However, research on argumentation in the context of K-12 mathematics and science is rarely carried out by researchers in Southeast Asia, the Middle East, and Africa.

In terms of the research subject, secondary school students are populations that are often used as research samples in the context of K-12 science, while in the context of K-12 mathematics, elementary school students are the population most often used as research samples. This is in accordance with Dovigo (2016), indicating that educational studies on argumentation topic have generally focused on primary and secondary school over the years. Furthermore, qualitative research methods are methods that are often used in both contexts. On the contrary, teaching experiments are the design most often used in both research contexts. The use of research methods and design in the context of K-12 science is more varied than research in the context of K-12 mathematics.

Toulmin's is the research model most often used for the analysis of student's argumentation activities in both contexts. A number of studies have used Toulmin's model of argumentation to investigate the structure of argument (e.g., Conner et al., 2014; Lin & Hung, 2016). In general, there are more research models applied to the study of argumentation in the context of K-12 science. There are also more research settings and research topics applied to argumentation studies in K-12 science contrasted to K-12 mathematics. Nevertheless, the average article that applies a variety of methods and designs, models, settings, and research topics is still relatively low. Therefore, further research on argumentation in both contexts particularly in K-12 mathematics needs to be conducted with different methods, models, settings, and topics, such as across STEM domains.

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