JPII 11(1) (2022) 171-184

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

INTEGRATING READING AS EVIDENCE TO ENHANCE ARGUMENTATION IN SCIENTIFIC READING-BASED INQUIRY: A DESIGN-BASED RESEARCH IN BIOLOGY CLASSROOM

R. M. Probosari*[1], S. Sajidan[2], S. Suranto[3], B. A. Prayitno[4]

[1]Doctoral Program of Natural Science Education, Universitas Sebelas Maret, Indonesia
[2,4]Biology Education Study Program, Universitas Sebelas Maret, Indonesia
[3]Department of Biology, Universitas Sebelas Maret, Indonesia

DOI: 10.15294/jpii.v11i1.29350

Accepted: March 2nd 2021. Approved: March 30th 2022. Published: March 31st 2022

ABSTRACT

This study aims to design a Scientific Reading-based Inquiry (SRbI) model that supports argumentation skills development. The assessment of these skills refers to the Toulmin Argument Pattern (TAP), and the participants were Biology Education students in a state university. Furthermore, the Design-based Research (DBR) approach was adopted by combining exploratory studies, trials, and case studies as part of an iterative process. The intervention was formed based on design principles derived from literature review and findings from exploratory studies. Also, observations were made during the trial and intervention process. Data in assessments and observations of written and oral arguments were collected and descriptively analyzed. The study, in three iterations, produced a framework as the basis for the SRbI learning model, with five phases: Reading Orientation, Recapturing, Processing, Communicating, and Reviewing. Therefore, the application of this learning model had a significant impact on the development of students' argumentation skills.

© 2022 Science Education Study Program FMIPA UNNES Semarang

Keywords: argumentation; design-based research; inquiry; reading; SRbI

INTRODUCTION

Argumentation is a scientific skill widely recognized as the primary goal of science (Berland & McNeill, 2010; Cavagnetto & Hand, 2012; Erduran et al., 2015; Tsai, 2015; McNeill et al., 2016), especially concerning communication processes. Language plays a vital role in interpretation and knowledge construction, while an argument is considered a critical aspect of language practice (McDonald, 2017). In science learning, students are expected to appropriately evaluate information to provide accurate, evidence-based decisions through a scientific argumentation process (Dawson & Venville, 2010; Erduran et al., 2015). In line with this, classroom practice enhances science nature as a scientific product, process, and attitude.

Arguments in science classrooms need to be accommodated, especially to implement a learning environment and strategies tested to improve students' skills (Evagorou & Osborne, 2013). Scientific argumentation consists of data components, reasoning, warrant, backing, and claims (Toulmin, 2003). Furthermore, data is a collection of facts or empirical evidence used to support a statement or claim, while a warrant is used as a basis for reasons that link data and claims. The backing is a basic assumption that supports a warrant. In summary, a claim is at the same time a view that has been justified in an argument. Although almost all teachers have implemented discussion as a learning method, only a few students show argumentation skills. Some

***Correspondence Address**
E-mail: riezkymaya@fkip.uns.ac.id

teachers stated that students were categorized as able to argue when they could answer questions, regardless of whether they were fact-based or not. In addition to providing answers, argumentation activities need to provide feedback and scientifically defend their statements as a scientist does (Probosari et al., 2017). The observations made in four biology classes in a state university, Central Java, showed weakness in students' argumentation skills, especially in discussions (Probosari et al., 2016). In addition to not presenting evidence-based arguments, several students subjectively answered problems without appropriate scientific references. Also, most of them agreed with others' opinions and did not express their arguments.

Several approaches that aim to improve scientific argumentation skills have been applied in learning, for example, through the application of problem-based learning (Belland et al., 2011), collaborative practices (Sampson & Clark, 2009), dialogic argumentation (Crowell et al., 2014; Kuhn et al., 2016), pedagogical content knowledge (Knight-Bardsley & McNeill, 2016) and inquiry (Fielding-Wells et al., 2014; Erduran et al., 2015; Nichols et al., 2016). All these strategies are declared successful in improving scientific argumentation skills in science class with their respective strengths and weaknesses. This essentially refers to a special, evidence-based character and the justification of all scientific statements that support or oppose particular views.

The inquiry-based learning model is considered more appropriate because the argument is directly integrated with inquiry and scientific literacy activities. Therefore, learning leads to positioning, whether it supports, strengthens, opposes, or undermines previous scientific statements (Demircioğlu & Uçar, 2012; Fielding-Wells et al., 2014). Also, through inquiry, students fully understand science concepts by problem-solving based on strong evidence, through a process of authentic scientific discovery, correlating and accommodating thinking skills, as well as rationally and logically conducting scientific communication (Scherz et al., 2005; Kulgemeyer & Schecker, 2013; Parmin & Fibriana, 2020). This is not found in other strategies or learning models. Therefore, this phenomenon is strengthened by the increasing trend of using inquiry to improve arguments (Erduran et al., 2015). At the higher education level, an open inquiry is considered the most appropriate to optimize students' understanding of the nature of science following the objectives of science learning (Zion et al., 2020).

One of the challenges in inquiry-based learning is students' limitation in understanding the concept. Therefore, efforts need to homogenize the initial knowledge through reading activities before the inquiry. This underlies why reading is the basis for inquiry learning, structured and planned. Also, reading is an integral part of scientific inquiry, and it involves thinking, encourages concept development, supports inquiry, and fosters scientific habits (Koeneman et al., 2013; Enfield, 2014). Scientific reading activity is essentially the primary goal of learning science for various reasons. First, being the central practice of inquiry that underlies observation, measurement, and data analysis, reading is to seek definitions or find information and understand, interpret, analyze, and, if possible, criticize (Norris, 2012; Phillips et al., 2012). Second, reading scientific texts in science class reinforces the nature of science, including the scientific epistemology of every phenomenon that occurs in nature (Yarden et al., 2015). Concerning argumentation skills, reading provides a solid basis in terms of accuracy and data validity, evidence, and theories underlying a scientific statement (Renken & Nunez, 2010; Chin et al., 2015; Davila & Griffiths, 2016; Wang et al., 2016). There are minimal inquiry models that accommodate structured scientific reading as a fundamental activity in practice. Several research approaches oriented towards inquiry and argumentation include the Argument-Based Science Inquiry (Choi et al., 2014; Taylor et al., 2018; Sari & El, 2020), the Argument-Driven Inquiry (Cetin & Eymur, 2017; Eymur, 2018, 2019), and the Scientific Inquiry Learning Model (Eliyahu et al., 2020; Mesci et al., 2020). Although they contain inquiry steps in optimizing argumentation skills, these approaches do not explicitly include reading activity in the instructions.

In fact, as a source of knowledge that underlies every step of the inquiry, reading activities need to be accommodated further into certain parts of learning. According to the research objective, all students can read, but not all can give the meaning of the reading they read correctly, so scientific reading activities must be adequately maintained and planned. To prepare to be part of the scientific community, students in science classes need to engage in credible and valid scientific inquiry even if they are not doing it themselves. They need to understand and analyze the explanations made by the original researchers through their research articles. In addition, students should read the article critically by evaluating evidence, reasoning, and argumentation. Students' failure to understand the meaning and critical points of scientific reading can hinder the inquiry process, especially decision-making (Ma et al., 2014; Pritasari et al., 2015; Probosari, 2015). Several studies have shown an increase in argumentation skills through various learning models that introduce reading assignments. Students who previously had difficulty understanding facts, laws, principles, or scientific theories train to find the main ideas in the literature and relate new ideas to old knowledge, either through assimilation, accommodation, or equilibration (Pritasari et al., 2015; Probosari, 2015; Probosari et al., 2017; Probosari et al., 2019). The interviews also showed that learning assistance that accommodates reading assignments synergistically makes it easier for students to analyze the information they need in a structured and systematic way. Of course, some students need more intensive assistance because of their limited ability, but in general, skills to strengthen reasoning, explanation, and argumentation increase along with the increase in the volume and frequency of scientific reading activities. On the other hand, several learning approaches have included reading activities as the core of instruction, for example, Directed Reading Thinking Activity (Haggard, 2014), Survey, Question, Read, Recite, Review or SOAR, and Survey, Question, Read, Recite / Recall, and Review or SQ3R (Jairam et al., 2014). They can all demonstrate the steps in reading comprehension but do not refer to inquiry activities that lead to argumentation.

Therefore, building a learning model that explicitly integrates reading activities is necessary to strengthen knowledge and information that form argumentation skills. Scientific reading is intended to compile a list of facts, phenomena, methods, and scientific explanations from the references and integrate them with prior knowledge. Strategies to link and improve prior knowledge in reading activities use several ways: reading several different articles on the same problem or case, comparing and analyzing different methods, results, and reviews written from different perspectives, and evaluating new information that they never knew before. The results of the interviews showed that when students conveyed this information to others, their confidence to continue reading other references would increase so that they could use this new knowledge to develop reasoning according to problems. This condition happens to most of them, including students with high, medium, or even low academic abilities. Of course, the time required for each student varies according to their ability, but clearly, students feel more confident when conveying scientific information that they find themselves (Probosari et al., 2017, 2018, 2019). Scientific Reading-based Inquiry (SRbI) is developed by integrating reading as a fundamental part of inquiry activities in design-based research, which is tried out in various classroom interventions and iterations. In addition, SRbI facilitates argumentation skills, both structurally and in the construct, especially in strengthening students' prior knowledge through reading activities and constructing scientific ideas in communicative classroom discourse. The basic framework that underlies SRbI development is presented as follows:

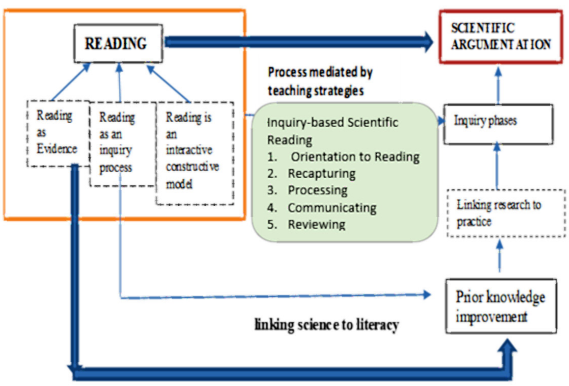

Figure 1. A Scheme Linking Reading, Inquiry, and Argumentation in SRbI

The picture above shows that the reading activity contains the steps for students to find evidence in reading, analyze the inquiry process experienced by scientists when formulating their findings, and then integrate all their findings constructively in scientific discussions. This activity accommodated the SRBI learning strategy that combines literacy with scientific practice. The main focus is on strengthening prior knowledge, which provides the basis for a complete research experience through a specific inquiry process for each individual and subsequently forms and strengthens scientific argumentation skills. SRbI is categorized in the information processing family (Joyce & Calhoun, 2009). Furthermore, the learning phases consist of Orientation to Reading, Recapturing, Processing, Communicating, and Reviewing (Probosari et al., 2019). Therefore, this study aims to design the SRbI model by developing a framework supporting argumentation skills development. In addition, SrbI will be used to overcome the weak argumentation skills at the tertiary level, especially in science class.

METHODS

The research was conducted in 2019-2020 at one of the biology education programs, a state university in Central Java, Indonesia, for four semesters and collaborated with two lecturers who taught Biology in Surakarta, Central Java, to design a learning model and test it in their class for four semesters. The students involved are third, and fourth-semester students, consisting of 25 participants consisting of 18 women and seven men between 19-21 years old with varying scientific reading abilities and communication. Data were collected from students' written and oral argumentation skills, lecturer and student notes, and interviews. The written argumentation data came from students' scientific writings on a predetermined theme, whereas the oral argumentation data came from recordings of their class presentations and discussions. Furthermore, the assessment of argumentation adopted TAP (Toulmin, 2003) and was descriptively analyzed. All instruments have been prepared and validated before implementation in the class. Also, items validation used the Rasch Model (Boone et al., 2014), while content validation was carried out by learning evaluation experts. In addition, an intervention in applying a hypothetical model of RSbI was carried out to oversee the development of argumentation skills in the classroom.

This study lasted for two years to contribute to learning theory and support students' scientific argumentation skills. A sequence design was made to achieve the goal and answer how to design a Scientific Reading-Based Inquiry model that supports scientific argumentation skills, which was equipped with learning materials, experiences, and a supportive environment such as the learning process, making the Design-based Research very appropriate to be applied. The DBR has been widely referred to as one of the qualitative deductive approaches in various educational studies, covering the process of design, development, experimentation, and evaluation (Plomp & Nieveen, 2013). DBR can synergize educational theory with practice to produce functional and practical learning designs based on strong, grounded theory combined with practical experience (empirically based). In particular, this study applies DBR to produce design principles that can solve real problems in learning. Therefore, DBR combines the ground from educational studies to design a learning environment that originates from theory and contains three main phases: preliminary, prototyping, and assessment. Data analysis used three ways: continuous formative analysis, intuitive analysis that provides direction in adjusting and developing interventions and programs according to theory and results in the field, and retrospective analysis carried out after all processes are completed (Mckenney & Mor, 2015).

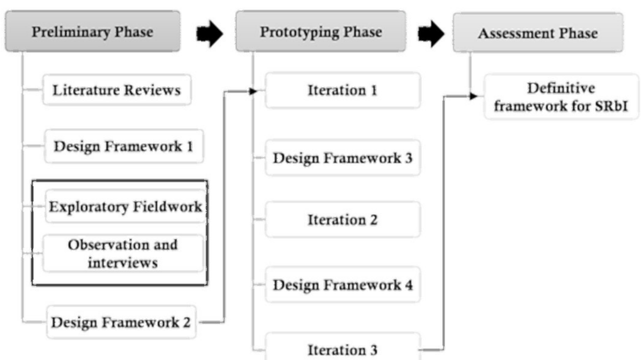

Figure 2. The Study Process in DBR Methodology, Adapting the Plomp Model (Plomp & Nieveen, 2013)

Interventions on limited scientific argumentation skills and the lack of massive scientific reading habits in science education students lead to the SRBI learning model. Detailed interventions are described in each design framework. Fieldwork implementation at the initial stage uses a design framework 1. Iteration 1 uses a design framework 2. Iterations 2 and 3, which are case studies, use frameworks 3 and 4. Each iteration stage requires ten meetings to naturally and gradually develop argumentation skills. In addition, the SRBI model implementation was chronologically observed to indicate a shift indeed influences changes in argumentation skills in learning habits.

RESULTS AND DISCUSSION

In this study, the intervention was carried out to develop a definitive model to guard students' scientific argumentation skills. Iteratively, the SRbI learning model has changed several times, starting from the implementation until a framework is obtained under the situation and conditions of students in the learning process. Meanwhile, changes from design framework 1 to 2 are based on findings from exploratory fieldwork, while changes to design frameworks 3, 4, and 5 are based on interventions adaptation and findings. In addition, design framework 1 was an initial design that showed the pedagogical principles that the formation of arguments begins with written and defended orally in class discussions. The theoretical underpinnings of design framework 1 are combined with initial facts from the field and input from the lecturer. The following is design framework 1.

Table 1. Design Framework 1

No	Design Framework 1
1.	Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase.
2.	Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase.
3.	Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase.
4.	Students should be actively involved in argumentative discussions in class through the Communicating phase.
5.	Students should be encouraged to reflect their knowledge on the argumentative classroom discussion to improve the argumentative papers they make through the Reviewing phase.

Interventions improvement are carried out based on previous iterations, and the literature is used to improve the results achieved in design framework 1.

Table 2. Interventions Development based on Findings

Design Framework 1	Activities	Findings	Design Framework 2
Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase.	Searching online and offline reference sources (individual activity)	The tendency to look for references from search engines in general Many students still have difficulty distinguishing between genres of scientific reading and their sources.	Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase. Lecturers need to provide special training regarding the character of the scientific reading genre and valid literature sources.
Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase.	Disaggregation of relevant information through appropriate references (individual activity)	Student difficulties in paraphrasing, especially from references in foreign languages The tendency to plagiarize through the "copy-paste" mechanism	Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase. Students need to know when to use quotations and when to paraphrase.

Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase.	Writing a paper that contains aspects of the argument, according to TAP (Toulmin, 2003) based on a literature review that has been previously read (individual activity)	Many students have structurally presented written arguments, but the content is still weak or difficult to confirm the truth.	Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase. Students need to know the various forms and structures of written arguments according to TAP.
Students should be actively involved in argumentative discussions in class through the Communicating phase.	Engaging in class presentations and individual argumentative discussions (group activity)	Time constraints do not allow students to engage optimally in argumentative discussions. The questions asked by the students did not allow for arguments.	Students need to be actively involved in argumentative discussions in class through the Communicating phase. Students need to learn how to argue and raise contradictory problems to allow argumentative dialogue.
Students should be encouraged to reflect on the argumentative classroom discussion to improve the argumentative papers they make through the Reviewing phase.	Documenting the results of argumentative discussions and revisions of previously written papers by integrating the results of discussions and reflections (individual activity)	Many students have not reflected their presentation results in their final paper as part of the improvement.	Students should be encouraged to reflect on the class discussion's arguments to improve the argumentative papers they make through the Reviewing phase. Students need to be encouraged to integrate reading skills and written and oral arguments synergistically.

Furthermore, design framework 2 is used in the class prototyping phase and counted in iteration 1. Based on the findings, additional literature review, and input from collaborators, design framework 3 is formulated as follows:

Table 3. Design Framework 3 based on Reflection of Design Framework 2

Design Framework 2	Supplement from Literature Review	Finding from Iteration 1	Design Framework 3
Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase. Lecturers need to provide special training regarding the character of the scientific reading genre and valid literature sources.	Scientific knowledge relies on one source of textual information and various representations, both text, print, and digital. Therefore, the selection of accurate sources needs to be considered (Bråten et al., 2013).	The tendency of looking for references from search engines in general Many students still have difficulty distinguishing between genres of scientific reading and their sources. The tendency to specifically look for references in Indonesian because of the difficulty in understanding a foreign language	Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase. Lecturers need to provide special training regarding the character of the scientific reading genre and valid literature sources. Students should be encouraged to use credible references without language barriers.

Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase. Students should know when to use quotations and when to paraphrase.	Reading more references allows students to make coherent interpretations from various points of view and evaluate specific information between references, for example, comparing data and claims in several similar references (Anmarkrud et al., 2014).	Student difficulties in paraphrasing, especially from references in foreign languages The tendency to plagiarize through the copy-paste mechanism Many students still do close reading activities and are only satisfied with what they read.	Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase. Students need to know when to use quotations and when to paraphrase. Students should be encouraged to do open reading to be motivated to read other references related to the problem.
Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase. Students should know the various forms and structures of written arguments according to TAP.	The selection of accurate reference sources affects more complex and justified arguments (Barzilai & Tzadok, 2015).	Many students have structurally presented written arguments, but the content is still weak or difficult to confirm the truth. Students still have difficulty distinguishing elements of argumentation. Sometimes the systematics of argumentative writing is not fulfilled; hence it is possible to accumulate certain elements, but on the other hand, it does not fulfill other elements.	Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase. Students should know the various forms and structures of written arguments according to TAP. Students need to be encouraged to fulfill the completeness of the argumentation elements and pay attention to their arguments' quality.
Students should be actively involved in argumentative discussions in class through the Communicating phase. Students need to learn how to argue and raise contradictory problems to allow argumentative dialogue.	Dialectical argumentation increases students' mastery of concepts (Larrain et al., 2014)	Time constraints do not allow students to engage optimally in argumentative discussions. The questions asked by the students did not allow for arguments. There are still many responses when asked questions in the form of opinions.	Students should be actively involved in argumentative discussions in class through the Communicating phase. Students need to learn how to argue and raise contradictory problems to allow argumentative dialogue. Students need to improve their argumentation skills based on facts, not opinions.
Students should be encouraged to reflect on the class discussion's arguments to improve the argumentative papers they make through the Reviewing phase. Students need to be encouraged to synergistically integrate reading skills, written arguments, and oral arguments.	After having an argumentative discussion, the reconciliation strategy helps them argue in a more reflective way (Yu & Jeng, 2016).	Some have not reflected on the presentation results in the final paper as an improvement after being confronted in a class discussion. Some students did not complete their arguments after engaging in argumentative class discourse. Some did not confirm their statements after engaging in argumentative discourses.	Students should be encouraged to reflect on the class discussion's arguments to improve the argumentative papers they make through the Reviewing phase. Students need to be encouraged to integrate reading skills and written and oral arguments synergistically. Students have to do positioning, whether it is reinforcing, revising, or even giving resistance to the statements that have been previously conveyed.

Iteration 2 was conducted in the same class in the following semester in 10 sessions. The results of the intuitive analysis were further refined in design framework 4 as follows:

Table 4. Design Framework 4

Design Framework 3	Intervention Sdaptation Related to SRbI based on Previous Activity and Findings	Findings	Design Framework 4
Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase. Lecturers need to provide special training regarding the character of the scientific reading genre and valid literature sources. Students should be encouraged to use credible references without language barriers.	Individual task: develop reading activities from various credible references to obtain information in a multi-perspective. Inventory of full-text database playlists containing integration between credible journals and books. Characterization of references based on their designation	Based on observation, only 8% of students still take reading from non-primary or non-reputable sources. There are still those who do not create a special folder to store references. Therefore, they often have difficulty accessing them quickly.	Students should be encouraged to find accurate and reputable reference sources through the Reading Orientation phase. Lecturers need to provide special training regarding the character of the scientific reading genre and valid literature sources. The use of software to organize references makes it easier to make citations or quickly access reading collections. Students should be encouraged to use credible references without language barriers.
Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase. They need to know when to use quotations and when to paraphrase. Students should be encouraged to do open reading to be motivated to read other references related to the problem.	Individual task: determining information that is considered important from a reading Reference inventory on the same topic.	12% of students still take references based on the top order that appears in search engines.	Students should be encouraged to read scientific literature and retrieve information from these reference sources through the Recapturing phase. Students should know when to use quotations and when to paraphrase. Students should be encouraged to do open reading to be motivated to read other references related to the problem. Students need to mark important parts of books or articles and make special notes when necessary.
Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase. Students should know the various forms and structures of written arguments according to TAP. Students need to be encouraged to fulfill the completeness of the argumentation elements and pay attention to their arguments' quality.	Individual task: writing a paper containing elements of argumentation	16% of students have not systematically presented papers. 20% of students do not present data in a multi-representative way	Students should be encouraged to make initial argumentative papers before presenting them individually through the Processing phase. Students should know the various forms and structures of written arguments according to TAP. Students should know the types and characters of argumentation elements. Students need to be encouraged to fulfill the completeness of the argumentation elements and pay attention to the quality of their arguments.

Students should be actively involved in argumentative discussions in class through the Communicating phase. Students need to learn how to argue and raise contradictory problems to allow argumentative dialogue. Students need to improve their argumentation skills based on facts, not opinions.	Work independently but remain collaborative when sharing ideas.	8% seemed to give answers by reading, not based on their understanding. 32% only responded in approval and did not provide additional opinions or arguments in class discussions. Some still dominated rebuttal activities in class discussions.	Students should be actively involved in argumentative discussions in class through the Communicating phase. They need to learn how to argue and raise contradictory problems to allow argumentative dialogue. Students need to improve their argumentation skills based on facts, not opinions. Students should have knowledge about the topics discussed before participating. Students who make presentations should prepare representative, systematic, structured media and provide a clear picture of the issues raised.
Students should be encouraged to reflect on the class discussion's arguments to improve the argumentative papers they make through the Reviewing phase. Students need to be encouraged to integrate reading skills and written and oral arguments synergistically. Students have to do positioning, whether it is reinforcing, revising, or even giving resistance to the statements that have been previously conveyed.	Individual work: revising the initial paper by incorporating findings or additional knowledge gained after participating in argumentative discussions.	All revised papers show improvement compared to before the students had an argumentative discussion.	Students should be encouraged to reflect on the class discussion's arguments to improve the argumentative papers they make through the Reviewing phase. Students need to be encouraged to synergistically integrate reading skills, written and oral arguments. Students have to do positioning, whether it is reinforcing, revising, or even giving resistance to the statements that have been previously conveyed. Students need to be accustomed to documenting in detail the findings or information they get to make optimal improvement.

Design framework 4 has been implemented in iteration 3, with two different classes consisting of 50 students in the following semester. Framework 4 only provided minor improvements to framework 3. At the end of iteration 3, it was found that an increasing trend is similar to iteration 2. Therefore, this study may have a constant effect when it is continued in the next iteration. The students followed all the steps of SRbI learning, and no major findings need to be anticipated. Hence, a definitive framework of SRbI can be formulated which provides a basis as well as learning experiences related to scientific argumentation skills as follows:

Table 5. Argumentation Activities Facilitated by SRbI

No	SRbI Phases	Argumentation Elements	Argumentation Activities
1	Reading Orientation	Claim	Statements compilation from various literary sources
		Data	Data collection from various literature.
2	Recapturing	Warrant	Inventory of the logical reasons related to the problem.
		Backing	Search for theoretical or practical foundations that reinforce logical reasons (warrant).
		Qualifier	Give special consideration or limitations on certain conditions.

3	Processing	Claim	Formulate a statement after critically reading various literature.
		Data	Select data in multiple representations relating to the problem
		Warrant	Sharpen the logical reasons related to the problem.
		Backing	Tracing the theoretical or practical basis in a multidimensional manner
		Qualifier	Give special consideration or limitations on certain conditions from various perspectives.
4	Communicating	Claim	Coherently convey statements.
		Data	Account for the data and sources used.
		Warrant	Provide rational reinforcement.
		Backing	Presentation of the theoretical basis used.
		Qualifier	Give special consideration or conditions that occur.
		Rebuttal	Give rebuttals or corrections from a different perspective.
5	Reviewing	Claim	Reaffirming the statements made.
		Data	Justification of the evidence used.
		Warrant	Justification of the rational reasons underlying the statement
		Backing	The basic justification that corroborates reason
		Qualifier	Reaffirm and provide recommendations on the types of statements made, whether they apply in general or in certain conditions.
		Rebuttal	Provide corrections to previous statements, either strengthening or weakening.

The implementation of SRbI in the classroom for three iterations showed an increasing trend of argumentation skills shown in Figure 3. The argumentation skills assessment results showed an increase in all aspects, including claims, data, warrant, backing, qualifier, and rebuttal after applying the SRbI. Each phase allows students to synergize and develop the knowledge they acquire collaboratively. Most of them formulate claims and data elements in Reading Orientation and Recapturing. Claims are made to confirm their opinion on the issues discussed. Data is used to strengthen the given claim. Warrant and backing elements are most commonly found in Processing and Communicating. Warrants are used to confirm empirical data based on research conducted. The backing is used to provide a theoretical basis under the claim. Elements of justification are practiced in the Communicating phase when they defend what they believe when confronted by others, while qualifiers are primarily formulated in the Review when they provide a level of confidence in what is conveyed.

This study highlighted changes in students' argumentation skills at the beginning and end of the intervention and found a shift in a positive direction. The approach to equip students in arguing was carried out to organize and retrieve the necessary information and provide a knowledge base to anticipate things contrary to what is conveyed or highlight the weaknesses of other people's views. Thus far, SRbI implementation has been focused on (1) encouraging students to make clear statements regarding a problem; (2) demonstrating or describing how they obtain data that supports their statements; (3) clarifying what they mean, especially when there are people who have different views; (4) challenging students to see problems in a multi-perspective way; (5) helping them track arguments, and (6) stimulating their independence in seeking credible learning resources.

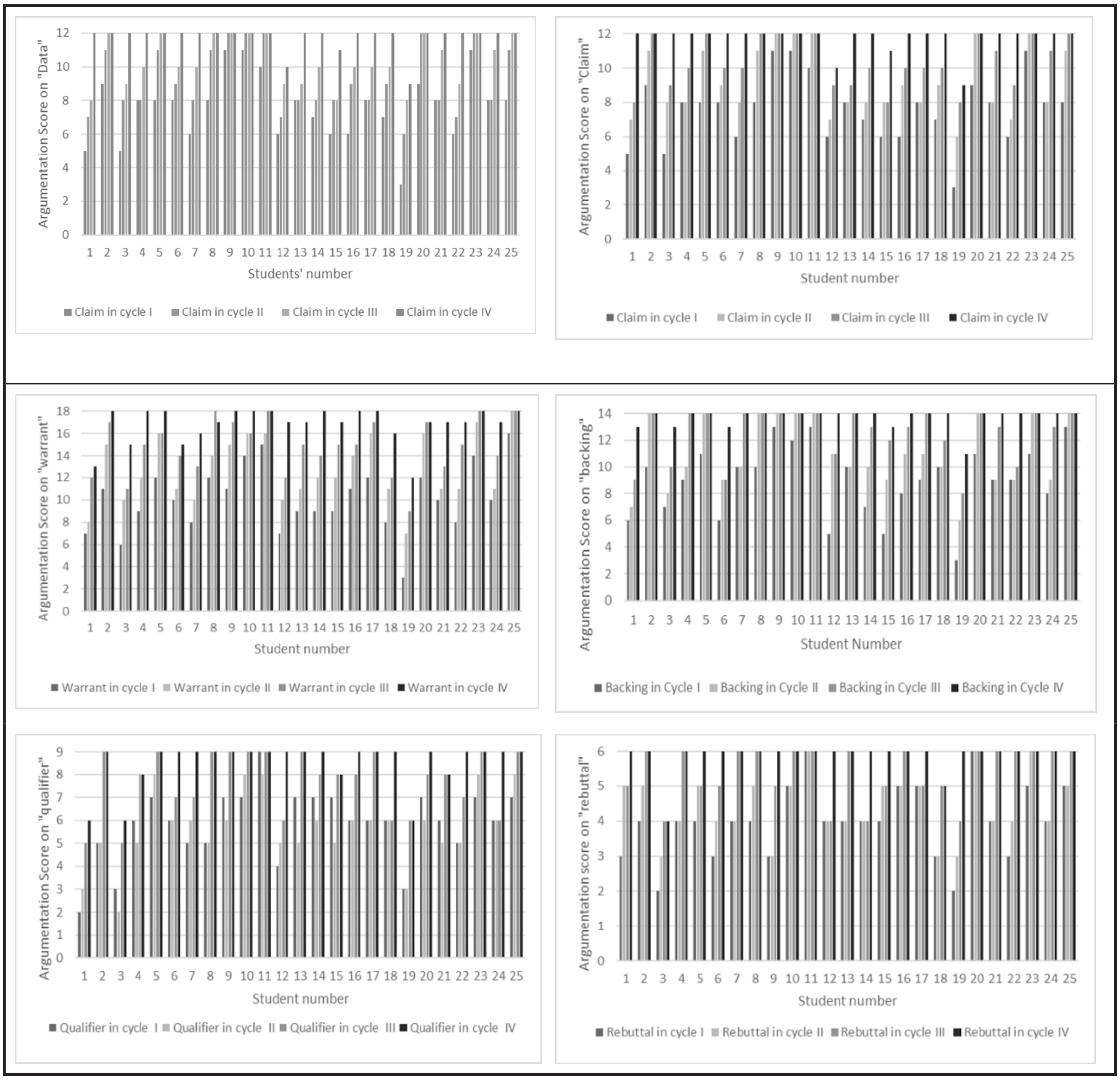

Figure 3. Students' Argumentation Scores based on TAP during the SRbI Implementation

Several studies have shown that argumentation skills improve when students socialize with others (Zohar & Nemet, 2002; Jin & Jeong, 2013; Fielding-Wells et al., 2014; Probosari et al., 2019). Also, video recordings and lecturer notes during the trial and case studies in all iterations showed SRBI's effectiveness in stimulating students to argue, both in writing and oral. Furthermore, the more the disagreements, the more the argument quality (Felton & Kuhn, 2001; Felton & Herko, 2004). The results showed that initially, the students did not raise many differences of opinion and argumentative discussions were dominated by the phrases "agree" and "disagree" in all trials and iterations. Most of the difficulties experienced were shown when asked to use references or data sources that substantiate or support their arguments. This has led to the dominance of opinion-based arguments rather than scientific ones. This is when the willingness and skills to read scientific references from various credible sources take a role.

The argumentation quality can be assessed using the framework by Zohar and Nemet (2002), which is a TAP development. They formulate that an argument consists of a statement or conclusion and its justification or the reasons or support. An argument is considered strong when many justifications support its conclusions and combine relevant, specific, and accurate scientific concepts. Meanwhile, weak arguments are composed of irrelevant individual conclusions based on justification. Furthermore, Zohar and Nemet (2002) simplified the data, warrant, and backing in TAP into one category, namely justification, to make it easier to analyze. Justification is analyzed to determine whether the arguments made are (a) without consideration of scientific knowledge, (b) inaccurate scientific knowledge, (c) scientific knowledge is not specific or sufficient, or (d) scientific knowledge is correct. The assessment results of students' written and oral arguments showed an increase in justification, which was indicated by a score comparison of all the arguments elements. Therefore, it can be stated that the arguments made after the existence of SRbI showed consideration of scientific knowledge, especially those assimilated reading activities and classroom discourses.

CONCLUSION

The results showed that the Scientific Reading-based Inquiry (SRbI) model had been developed, supporting scientific argumentation skills on four different occasions, different students, and different learning materials. These skills are initiated after the students experience all stages of assimilation, accommodation, and equilibration knowledge through reading activities and be directly involved in argumentative discussions. In addition, each phase of SRbI allows students to synergize and collaboratively develop the knowledge they have acquired. However, further validation of 'design generalizations' at a broader level needs to be carried out through a balance of design principles and theory development regarding their effectiveness.

REFERENCES

Anmarkrud, O., Braten, I., & Stromso, H. I. (2014). Multiple-Documents Literacy : Strategic Processing, Source Awareness, and Argumentation when Reading Multiple Conflicting Documents. *Learning and Individual Differences*, *30*, 64–76.

Barzilai, S., & Tzadok, E. (2015). Sourcing while Reading Divergent Expert Accounts: Pathways from Views of Knowing to Written Argumentation. *Instructional Science*, *43*, 737–766.

Belland, B. R., Glazewski, K. D., & Richardson, J. C. (2011). Problem-based Learning and Argumentation: Testing a Scaffolding Framework to Support Middle School Students' Creation of Evidence-based Arguments. *Instructional Science*, *39*(5), 667–694.

Berland, L. K., & McNeill, K. L. (2010). A learning Progression for Scientific Argumentation: Understanding Student Work and Designing Supportive Instructional Contexts. *Science Education*, *94*(5), 765–793.

Boone, W. J., Yale, M. S., & Staver, J. R. (2014). Rasch Analysis in the Human Sciences. In *Rasch Analysis in the Human Sciences*. Springer.

Bråten, I., Ferguson, L. E., Anmarkrud, Ø., & Strømsø, H. I. (2013). Prediction of learning and comprehension when adolescents read multiple texts: The roles of word-level processing, strategic approach, and reading motivation. *Reading and Writing*, *26*(3), 321–348.

Cavagnetto, A., & Hand, B. (2012). The Importance of Embedding Argument Within Science Classrooms. In M. S. Khine (Ed.), *Perspectives on Scientific Argumentation: Theory, Practice and ResearchTheory, Practice and Research* (pp. 39–53). Springer Netherlands.

Cetin, P. S., & Eymur, G. (2017). Developing Students' Scientific Writing and Presentation Skills through Argument Driven Inquiry: An Exploratory Study. *Journal of Chemical Education*, *94*(7), 837–843.

Chin, C. C., Yang, W. C., & Tuan, H. L. (2015). Argumentation in a Socioscientific Context and its Influence on Fundamental and Derived Science Literacies. *International Journal of Science and Mathematics Education*, *14*(4), 603–617.

Choi, A., Klein, V., & Hershberger, S. (2014). Success, Difficulty, and Instructional Strategy To Enact an Argument-Based Inquiry Approach: Experiences of Elementary Teachers. *International Journal of Science and Mathematics Education*, *13*(5), 991–1011.

Crowell, A., Crowell, A., & Kuhn, D. (2014). Developing Dialogic Argumentation Skills : A 3-year Intervention Study. *Journal of Cognition and Development*, *15*(2), 363–381.

Davila, Y. C., & Griffiths, N. (2016). Supporting Student Transition : Embedding Reading Practices into the First Year Science Curriculum. *Students Transitions Achievement Retention & Success*, *July*, 1–5.

Dawson, V. M., & Venville, G. (2010). Teaching Strategies for Developing Students' Argumentation Skills about Socioscientific Issues in high School Genetics. *Research in Science Education*, *40*(2), 133–148.

Demircioğlu, T., & Uçar, S. (2012). The Effect of Argument-Driven Inquiry on Pre-Service Science Teachers' Attitudes and Argumentation Skills. *Procedia - Social and Behavioral Sciences*, *46*, 5035–5039.

Eliyahu, E. Ben, Assaraf, O. B. Z., & Lederman, J. S. (2020). Do Not Just Do Science Inquiry, Understand It! The Views of Scientific Inquiry of Israeli Middle School Students Enrolled in a Scientific Reserve Course. *Research in Science Education*.

Enfield, M. (2014). Reading Scientifically: Practices Supporting Intertextual Reading Using Science Knowledge. *Journal of Science Teacher Education*, *25*(4), 395–412.

Erduran, S., Ozdem, Y., & Park, J.-Y. (2015). Research Trends on Argumentation in Science Education : a Journal Content Analysis from 1998 – 2014. *International Journal of STEM Education*, *2*(5), 1–12.

Evagorou, M., & Osborne, J. (2013). Exploring Young Students' Collaborative Argumentation within a Socioscientific Issue. *Journal of Research in Science Teaching*, *50*(2).

Eymur, G. (2018). Developing High School Students' Self-Efficacy and Perceptions about Inquiry and Laboratory Skills through Argument-Driven Inquiry. *Journal of Chemical Education*, *95*(5), 709–715.

Eymur, G. (2019). The influence of the Explicit Nature of Science Instruction Embedded in the Argument-Driven Inquiry Method in Chemistry Laboratories on High School Students' Conceptions about the Nature of Science. *Chemistry Education Research and Practice*, *20*(1), 17–29.

Felton, M., & Herko, S. (2004). From Dialogue to Two-Sided Argument: Scaffolding Adolescents' Persuasive Writing. *Journal of Adolescent & Adult Literacy*, *47*(8), 672–683.

Felton, M., & Kuhn, D. (2001). The Development of Argumentive Discourse Skill. *Discourse Processes*, *32*(2), 135–153.

Fielding-Wells, J., Dole, S., & Makar, K. (2014). Inquiry Pedagogy to Promote Emerging Proportional Reasoning in Primary Students. *Mathematics Education Research Journal*, *26*(1), 47–77.

Haggard, M. R. (2014). Developing Critical Thinking with the Directed Reading-Thinking Activity. *The Reading Teacher*, *41*(6), 526–533.

Jairam, D., Kiewra, K. A., & Marxhausen, M. P. K. (2014). SOAR versus SQ3R : a Test of Two Study Systems. *Instructional Science*, *42*, 409–420.

Jin, L., & Jeong, A. (2013). Learning Achieved in Structured Online Debates: Levels of Learning and Types of Postings. *Instructional Science*, *41*(6), 1141–1152.

Joyce, B., & Calhoun, E. (2009). Three Sides of Teaching: Styles, Models, and Diversity. *International Handbook of Research on Teachers and Teaching*, 645–652.

Knight-Bardsley, A., & McNeill, K. L. (2016). Teachers's Pedagogical Design Capacity for Scientific Argumentation. *Science Education*, *100*(4).

Koeneman, M., Goedhart, M., & Ossevoort, M. (2013). Introducing Pre-university Students to Primary Scientific Literature Through Argumentation Analysis. *Research in Science Education*, *43*(5), 2009–2034.

Kuhn, D., Hemberger, L., & Khait, V. (2016). Dialogic argumentation as a bridge to argumentative thinking and writing. *Infancia y Aprendizaje*, *39*(1), 25–48.

Kulgemeyer, C., & Schecker, H. (2013). Students Explaining Science-Assessment of Science Communication Competence. *Research in Science Education*, *43*(6), 2235–2256.

Larrain, A., Howe, C., & Cerda, J. (2014). Argumentation in Whole-Class Teaching and Science Learning. *Psykhe (Santiago)*, *23*(2), 1–15.

Ma, B., Katsh-singer, R., Pimentel, D., Gonzalez-howard, M., & Mcneill, K. L. (2014). *Supporting All Students in Writing Scientific Arguments*.

McDonald, C. V. (2017). Exploring Nature of Science and Argumentation in Science Education. In *Science Education: A Global Perspective* (pp. 7–43). Springer International Publishing.

Mckenney, S., & Mor, Y. (2015). Supporting Teachers in Data-Informed Educational Design. *British Journal of Educational Technology*, *46*(2), 265–280.

McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2016). Pedagogical Content Knowledge of Argumentation: Using Classroom Contexts to Assess High-Quality PCK rather than pseudoargumentation. *Journal of Research in Science Teaching*, *53*(2), 261–290.

Mesci, G., Schwartz, R. S., & Pleasants, B. A. S. (2020). Enabling Factors of Preservice Science Teachers' Pedagogical Content Knowledge for Nature of Science and Nature of Scientific Inquiry. *Science and Education*, *29*(2), 263–297.

Nichols, K., Gillies, R., & Hedberg, J. (2016). Argumentation-Based Collaborative Inquiry in Science Through Representational Work: Impact on Primary Students' Representational Fluency. *Research in Science Education*, *46*, 343–364.

Norris, S. P. (2012). Reading for evidence and interpreting visualizations in mathematics and science education. *Reading for Evidence and Interpreting Visualizations in Mathematics and Science Education*, *9789460919*, 1–208.

Parmin, P., & Fibriana, F. (2020). The Reconstruction of Indigenous Knowledge about Golobe (Hornstedtia alliacea) as a Natural Resource Conservation Study for Prospective Teachers' Scientific Literacy. *Al-Ta lim Journal, 27*(2), 115-126.

Phillips, L. M., Norris, S. P., & Macnab, J. S. (2012). *Model And Modelling in Science Education: Visualization in Mathematics, Reading and Science Education* (Vol. 5, Issue 2). Springer.

Plomp, T., & Nieveen, N. (2013). *Educational Design Research, Part A : An Introduction* (T. Plomp & N. Nieveen (eds.)). SLO.

Pritasari, C., Dwiastuti, S., & Probosari, R. M. (2015). The Argumentation Capacity Improvement Through The Problem Based Learning Implementation in Class X MIA 1 SMA Batik 2 Surakarta. *Jurnal Pendidikan IPA Indonesia*, *4*(2), 158–163.

Probosari, R. M. (2015). Improvement of Students's Scientific Writing of Biology Education of Sebelas Maret University Through Reading Project Based Reading. *Jurnal Pendidikan IPA Indonesia*, *4*(1), 31–35.

Probosari, R. M., Rami, M., Harlita, Indrowati, M., & Sajidan. (2016). Profil Keterampilan Argumentasi Ilmiah Mahasiswa Pendidikan Biologi FKIP UNS pada Mata Kuliah Anatomi Tumbuhan. *Bioedukasi*, *9*(2007), 29–33.

Probosari, R. M., Sajidan, Suranto, Prayitno, B. A., & Widyastuti, F. (2017). Modelling Scientific Argumentation in the Classroom : Teachers

Perception and Practice. *Journal of Physics: Conference Series*, *365*(`), 011001.

Probosari, R. M., Widyastuti, F., Sajidan, S., Suranto, S., & Prayitno, B. A. (2018). Reading for Tracing Evidence: Developing Scientific Knowledge through Science Text. *Journal of Physics: Conference Series*, *1022*(1), 1–5.

Probosari, R. M., Widyastuti, F., Sajidan, S., Suranto, S., & Prayitno, B. A. (2019). Improving Scientific Argumentation: Opportunities and Barriers Analysis in Inquiry-based Scientific Reading. *Journal of Physics: Conference Series*, *1280*, 1–7.

Probosari, R. M., Widyastuti, F., Sajidan, Suranto, & Prayitno, B. A. (2019). Students' Argument Style Through Scientific Reading-based Inquiry: Improving Argumentation Skill in Higher Education. *AIP Conference Proceedings*, *2194*(020088), 1–7.

Renken, M. D., & Nunez, N. (2010). Evidence for Improved Conclusion Accuracy after Reading about Rather than Conducting a Belief-inconsistent Simple Physics Experiment. *Applied Cognitive Psychology*, *24*(6), 792–811.

Sampson, V., & Clark, D. (2009). The Impact of Collaboration on the Outcomes of Scientific Argumentation. *Science Education*, *93*(3), 448–484.

Sari, I., & El Islami, R. (2020). The Effectiveness of Scientific Argumentation Strategy towards the Various Learning Outcomes and Educational Levels Five Over the Years in Science Education. *Journal of Innovation in Educational and Cultural Research*, *1*(2), 52-57.

Scherz, Z., Spektor-Levy, O., & Eylon, B. A. T. S. (2005). Scientific Communication: An Instructional Program for High-Order Learning Skills and Its Impact on Students' Performance. In K. Boersma, M. Goedhart, O. de Jong, & H. Eijkelhof (Eds.), *Research and the Quality of Science Education* (pp. 231–243). Springer.

Taylor, J. C., Tseng, C., Murillo, A., Therrien, W., & Hand, B. (2018). Using Argument-based Science Inquiry to Improve Science Achievement for Students with Disabilities in Inclusive Classrooms. *Journal of Science Education for Students with Disabilities*, *21*(1), 1–14.

Toulmin, S. E. (2003). *The Uses of Argument, Updated Edition*. Cambridge University Press.

Tsai, C. (2015). *Improving Students' PISA Scientific Competencies Through Online Argumentation Improving Students' PISA Scientific Competencies Through Online Argumentation*. *November*, 1–2.

Wang, P., Chen, Z., Kasimu, R., Chen, Y., Zhang, X., & Gai, J. (2016). Inquiry Into the Independent Reading Development of First-Generation College Graduates With Advanced Degrees. *Journal of Literacy Research*, *48*(1), 105.

Yarden, A., Norris, S. P., & Phillips, L. M. (2015). Adapted Primary Literature The Use of Authentic Scientific Texts in Secondary Schools. In *Innovations in Science Education and Technology* (Vol. 22). Springer Science+Business Media Dordrecht.

Yu, R. L., & Jeng, F. H. (2016). The Analysis and Reconciliation of Students' Rebuttals in Argumentation Activities. *International Journal of Science Education*, *38*(1), 130–155.

Zion, M., Schwartz, R. S., Rimerman-Shmueli, E., & Adler, I. (2020). Supporting Teachers' Understanding of Nature of Science and Inquiry Through Personal Experience and Perception of Inquiry as a Dynamic Process. *Research in Science Education*, *50*(4), 1281–1304.

Zohar, A., & Nemet, F. (2002). Fostering Students' Knowledge and Argumentation Skills Through Dilemmas in Human Genetics. *Journal of Research in Science Teaching*, *39*(1), 35–62.