Improving scientific argumentation: opportunities and barriers analysis in inquiry-based scientific reading

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Abstract. Reading, as an inseparable part of science inquiry, is a strategy for concept understanding and building knowledge through literature. The purpose of this study was to examine opportunities and barriers of the development of 2nd-year college students’ scientific argumentation through reading activity. The practice of argumentation, as part of scientific communication, is conducted over one semester on continuous topic using inquiry-based reading instructions. This collaborative action research was held in one of the science education study programs in Central Java, Indonesia. Data sources included class discussions concentrated on individual presentation that occurred in nine weeks periods, students’ portfolios, questionnaires, and lecturer field notes. The opportunities and barriers of inquiry-based reading were analysed through Rasch analysis model. The results showed that there are many students who lack understanding of scientific reading strategies and how to use the information obtained to build strong arguments. Scientific reading culture is still very low, even though through habituation this can be resolved. Teaching strategies for doing inquiry-based reading in practice are discussed and the implications of these findings were highlighted in relation to develop sharper insight of scientific argumentation in science classrooms.

1. Introduction
Argumentation is very important in science learning. High-level thinking ability in science education requires student’s ability in answering and providing solutions to the phenomena that arises in the real world in a logical and scientific ways. This problem solving should be stated in a statement that contains evidence and has been justified by clear argumentation [1]. According to scientific argumentation skills, scientific reading provides a very strong basis in terms of accuracy and validity of data, evidence, and theory underlying a scientific statement [2–7]. Scientific argumentation in classes are not only implemented through debating without concrete evidence or just simply proving the right or wrong. Scientific explanations in a context must be verified, communicated, contradicted if necessary, and argument able. The arguments in classrooms should be contained in the curriculum, especially in environments and learning strategies that have tested improving student argumentation [8]. Based on its structure, scientific argumentation consists of elements; data, reasoning, warrant, backing, and claims [9–11]. Data becomes a set of facts or truths made to state or claim, while warrant is used to associate data and claim. Backing is the basis that supports warrant. In summary, claim is also stating as a part that has been justified in problems.

Reading, as an inseparable part of science inquiry, is a strategy for understanding matter and building knowledge through literature [12]. Reading activities involve thinking, encouraging the development of concepts, supporting inquiry, and cultivating students' scientific thinking habits [5,13–17]. Scientific
reading activities cannot be separated from the mental process used by the reader in understanding the texts. They include the processes of searching, analyzing, integrating text with various representations, and how to use the information obtained to determine attitudes, decisions and responses to social scientific issues that occur [18,19]. Scientific readings have different characteristics than non-scientific readings, especially in terms of information absorption and how this information is used [20–22]. Scientific readings in various forms, for examples textbooks, journals, or other types of reading contains scientific facts, principles, theories, and procedures related to scientific activities [14,23].

Focus of this study is reading as the basis, companion, and reinforcement of students’ inquiry. Inquiry is considered a way to find the truth, whereas reading means justifying opinions or ideas obtained from the activities that the expected truth will emerge. Inquiry-based Scientific Reading (IbSR) is an inquiry development model that accommodates scientific reading in inquiry-based learning steps through specific phases to emphasize the position of reading as a part of inquiry. Inquiry activity through scientific reading is one of epistemological evidence to science [16]. When interpreting a text, the readers understand the content through the knowledge they have acquired before, or the experience they have passed [24,25]. This interpretation does not apply literally but includes the essence implicit in it. The less initial knowledge they have, the greater effort must be made to extract the information from the scientific reading [26]. The implementation of Inquiry-based Scientific Reading (IbSR) consists of several phases as follows:

1.1. Orientation to reading
Students are stimulated to look for problems related to plant reproduction through reading assignments and scientific literature related to the concepts discussed. Lecturers and students negotiate topics and issues to be raised. The facilities used are accredited scientific articles and reading comprehension rubrics.

1.2. Recapturing
Students identify concepts derived from reading assignments. The concept is mapped according to key words from the description of observations adjusted to basic competencies. Students combine concepts, focus on the desired content, and look for other scientific literatures as a comparison.

1.3. Processing
Students determine the focus of inquiry in accordance with the expected competencies, forming an authentic statement based on personal statements or the results of the study and seeking the proof through investigation or experiment. Students look for relationships between written information, such as causal relationships, success, and the underlying arguments with new evidence obtained after experimenting.

1.4. Communicating
Students communicate the results of the investigation obtained, analyze the information obtained, develop an explanation model (new), review and discuss the solutions obtained, and determine some solutions. Class discourse is directed in argumentative conditions through active discussion. Lecturers facilitate students to integrate the concepts they produce with the concepts adopted by scientific experts.

1.5. Reviewing
Students check again and deepen understanding based on findings or inputs from the results of the discussion. The lecturer invites students to consider the form of improvement and follow up all stages of learning that have been carried out. Moreover, students give recommendations for real actions can be applied and provide reading assignments for the next material.

In many cases, lecturers face several challenges to effectively integrate argumentation into their classroom instructions. The argumentative discourse in the class generally only assessed the active communication of students in it, but not evaluate the quality of the arguments itself. This research is intended to analyze the practice of argumentation in the class as a basis for evaluating arguments as a
further step. The purpose of this case study was to examine opportunities and barriers of the development of 2nd-year college students’ scientific argumentation through Inquiry-based Scientific Reading practice in the classrooms.

2. Methods
This study was conducted in Biology Education Program in Sebelas Maret University, Indonesia. The population consists of fifty-three second year students who took Plant Embryology dan Reproduction subjects. In order to catch the practice of Inquiry-based Scientific Reading (IbSR), we accumulated two kinds of data, qualitative and quantitative, in a collaborative action research [27] which covered thinking and argumentation processes from all participations in the classroom. This research is aimed to make learning model designs. Inquiry-based Scientific Reading (IbSR) is built in accordance with constructivist learning theory as an effort to improve the quality of scientific argumentation while building a stronger theory. Data collections are structured around emerging phenomena that are important for describing the cases in terms of the research questions. The data were collected based on the phenomenon that occurs, as an important evidence to answer the research problems, namely the opportunities and barriers faced by students during the practice of scientific arguments through Inquiry-based Scientific Reading (IbSR). In this study, we used the Rasch measurement model [28–30] to test the easiest and the most difficult steps felt by the students. Although both assessed the same cognitive skills; argumentation, it needed to be proven empirically whether one step was easier or more difficult.

3. Results and Discussion
This study was conducted by giving an assessment to see the difficulties and challenges faced by students in building scientific arguments through the implementation of IbSR. Students analysed some articles based on several topics of anatomy of meristem tissues, dermal tissues, grounds tissues, and vascular tissues. Each student took one main reference and at least eight supporting articles. Inquiry skills through scientific reading activities are reflected in all IbSR steps, starting from the selection of research articles according to the topic of the study, how to highlight specific characteristics of the topics studied and how they determine attitudes when conducting argumentative discourse. The results of scientific reading activities are expressed in an essay written structurally and systematically in accordance with the rules of argumentation, especially through the description of argumentation diagrams [9,31].

Assessment of verbal argumentation skills is carried out when each student made an individual presentation about the results of thinking they have gotten. Each presentation will get responses in terms of questions, feedback, or objections from other participants. At the end of the class discussion, each student gave a statement intended to reinforce the idea he made, both in the form of reaffirming the claim or revising his original claim. The argumentation element evaluated refers to the Toulmin Argument Pattern (TAP) which targeted the skill of retrieving data, formulating claims, conducting warrants, determining backings and qualifiers, and conducting rebuttal if necessary [9,31]. The instrument referred to the six elements of argument; six indicators on data aspects (D1, D2, D3, D4, D5 and D6), six indicators on claim aspects (C1, C2, C3, C4, C5 and C6), six indicators on warrant aspects (W1, W2, W3, W4, W5 and W6), five indicators on backing aspects (B1, B2, B3, B4 and B5), four indicators on qualifier aspects (Q1, Q2, Q3 and Q4), and three indicators in rebuttal aspects (R1, R2 and R3). All indicators of argumentation are analyzed using the Rasch model to obtain facts and identify which indicators are the most difficult for students and how they are handled. The results of the Rasch model analysis can be seen as follows:
Figure 1. Person-Item Map of Argument Practice in the Classroom.

Figure 1, in the left side, illustrates the students' ability in arguing. Students with high abilities occupy the top position, while students with low ability occupy the bottom position. Meanwhile, in the right side of Figure 1, summarizes the individual response to argumentation aspects. Aspects that are considered the most difficult occupy the top position, while the easiest occupy the lowest position. The 16 of 30 students had above average abilities, four students had average abilities, and 13 students had below average abilities. Students number 23 had the highest ability, got maximum achievement compared to the others, followed by students' number 4, 18, 32, 11, and 22. They succeed in fulfilling all aspects of the argument, even with varying degrees. Students with low abilities were number 2, 9, 10, and 19. They only fulfilled five aspects of the argumentation aspects, they were C4, D1, D2, D3 and W6. Summary information on statistical results from all aspects of the argumentation can be seen in the table below:

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| Person Score | Count | Measure | Error | INFIT | OUTFIT |
|--------------|-------|---------|-------|-------|--------|
| Mean         | 51.6  | 29.9    | .53   | .28   | 1.08   |
| S.D.         | 7.7   | .3      | .58   | .08   | .39    |
| Max.         | 66.0  | 38.0    | 1.64  | .29   | 1.93   |
| Min.         | 35.0  | 29.0    | -.74  | .27   | .25    |
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Person RAW SCORE TO MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR 20) Person RAW SCORE *TEST* RELIABILITY = .77

Figure 2. Summary statistics of argumentation aspects
In the summary of the person response pattern, the infit value and mean square outfit are 1.0 or perfect, infit and z-std outfit are close to the ideal value of 0.0. Person reliability 0.73, means that the consistency of student responses is quite good and items reliability 0.83 means the quality of the items is good. Cronbach alpha value is 0.77 means the interaction between person and item is good. The table above shows the separation of students’ abilities: high, medium, and low. It also shows the difficulty level of the items given: difficult, medium and easy. It can be said that the instrument can measure students’ argumentation abilities in every aspect.

Argumentation practices in classroom can be noted. The observation shows that students tend to feel safe if they find the right answer, according to the lecture’s perceptions. They were seem not confident when they should made their own claims or evaluated claims made by their friends. Regarding of the use of literatures, some students were investigating the handbooks or references owned by lecturers, because they believe that all answers are there. In relation to the stages in implementing the IbSR, more attention must be paid to phase 1, the reading orientation. The cumulative nature of science makes a researcher or a prospective researcher needed to know everything that happens before they learn what is new. This can be done through scientific reading, especially research articles published from reputable journals [23,32]. The initial knowledge of inquiry is obtained from the study of journals or relevant research results, therefore the ability of students to extract the results of their studies and ideas becomes very important. So, the inquiry process that carried out actually goes to the desired tracks [18,21,22]. The appropriate reading orientation will facilitate students towards the next step, recapitulating the main idea found to obtain data and formulate claims, processing to get backing and warrant, communicating to maintain the initial claim made and reviewing to reaffirm the argument, especially if there is an argument counterpart given by other students.

During the presentation, students generally pay less attention to their friends’ exposure and busy correcting their own answers, looking safe in situations that should be argumentative. When there is a friend who gives a rebuttal, some students seem to immediately correct the answer without heeding the norm of argumentation, providing proof, warrant, and appropriate backing. They believe that an argument must be right if supported by references, without thinking that for the same cases some references might give different statements. Even, some students make analogy or metaphor to support their statements without being supported by empirical evidence. This shows that even though students have already known how to structure the right argument [9], but in practice, they do not follow the correct rules of argument. The argument in classroom discourse should not only produce arguments as a product, but also at the same time the argument process that occurs in it [33]. So, the students need to be enlightened that formal logic can only be used as an initial framework, but in process, the dialectical pragma works more. In IbSR, the basic skill that the students must have in argumentation is a strong tactical scientific reading.

4. Conclusion
In conclusion, although students are able to produce scientific arguments quantitatively on the material discussed, but in reality, not all aspects of the argumentation are achieved properly. The biggest obstacle is although the students seek references massively but there is not balanced with their scientific reading skills. So, there are still many students who put their opinions in their arguments. Further research needs to be done to find out how to practice scientific reading, especially for students who have language barriers and low ability. However, these results present intense evidences to promote the use of scientific reading as a part of inquiry, specifically to improve argumentation skills. The implication is that the inquiry based on scientific reading needs more concerns at all phases and it requires more times for students are used to it.

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