Students’ Scientific Argumentation Skills Based on Differences in Academic Ability

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Abstract. One of the skills students must possess in the 21st-century biology learning is scientific argumentation skills. Scientific argumentation skills are associated with a strong understanding of concepts and improved critical thinking skills and scientific literacy. The purpose of this study was to investigate the scientific argumentation skills of high school students with different academic abilities. The current study was designed as a survey which involved tenth graders from two public senior schools, SMAN 3 Malang and SMAN 7 Malang. The first served as the representative of students with high academic ability and the latter was appointed to represent the low achievers. The data were analyzed using an independent-samples t-test. The results showed that there were significant differences between the high and ability students’ scientific argumentation skills with a p-value of 0.003. Around 10.34% of the high achievers could perform level 1 argumentation skills, 74.41% of them were able to achieve level 2, and 17.24% of the students reported level 3 responses. Among the students with low academic ability, 12% had reached level 1 argumentation skills and 88% of them were only able to achieve level 2, indicating that no one (0%) could answer the test with level 3 responses. This condition suggests that it is important to implement an innovative learning.

1. Introduction
The education system around the world has developed a framework that emphasizes the development of 21st-century skills, knowledge, and attitudes [1]. New standards have been introduced to the curriculum [2], and therefore learners need to be prepared to learn the 21st-century skills to deal with the changing and growing today’s community [3]. Science is related to the universe. The implementation of science can be in the form of scientific work carried out inside and outside the classroom [4]. Learning that encourages students to ask questions and create arguments has been proven effective in improving students’ academic abilities.

The 21st-century skills also comprise argumentation skills. Scientific argumentation skills consist of the ability to literate, think critically, give reasons, and establish metacognitive communication [5]. Argumentation as an intellectual practice could engage students in constructing and criticizing scientific ideas [6]. Argumentation allows students to be involved in various scientific practices of society and culture through exploratory activities during learning and to deepen their understanding of the meaning of science [7]. Students will gain experiences from scientific practices and the experiences thus can be used to justify and support their arguments [8].
Scientific argumentation is usually associated with comprehension and knowledge [9] of scientific concepts and practices [10]. Students need to perform a set of activities in constructing a correct argument. The process begins with collecting claims and data (ground) and is followed by providing reasons (warrant), support (backing), qualifiers, and rebuttal [11]. Strong argumentation reasoning will bring a positive impact on the improvement of students’ scientific communication and writing skills [12].

Research has reported that the majority of students in Malang have poor performance in scientific argumentation skill [13]. IsTeacher’s classroom domination which normally results in students’ reluctance to get actively involved in the learning process can be one of the contributing factors to the issue to [14]. In addition, the results of the interviews conducted to biology teachers at SMA Negeri 1, SMA Negeri 3, SMA Negeri 4, SMA Negeri 7, and SMA Negeri 8 Malang indicated that students rarely provided good arguments. They were also unable to solve problems independently because they did not develop a good reading habit and failed to understand the learning materials. As a result, there was no significant improvement in the students’ learning achievement.

Academic abilities also influence students’ argumentation skills. Academic abilities are the abilities developed by students during the learning process and are usually affected by the students’ background knowledge. Background knowledge represents students’ mastery of previously learned topics. This knowledge forms a basis on which students can expand their understanding of new materials [15]. Some studies have shown that students’ academic abilities have an effect on the ability of the students to think critically, develop metacognition, and improve learning achievement [16]. However, little has been known about the impact of students’ academic abilities on the students’ argumentation skills even though a study has reported the relationship between argumentation-based learning, students’ academic abilities, and acquisition [17]. Considering the background of the research which has been explained in the previous sections, the present study thus aimed to investigate students’ scientific argumentation skills based on the differences in their academic abilities. The results of this study are hopefully beneficial for the improvement of learning in the classroom and the development of the students’ scientific argumentation skills.

2. Research Procedures
2.1. Research Design
This research was designed as a survey which employed a descriptive qualitative approach to investigating students’ scientific argumentation skills on different academic abilities. This descriptive study aimed to measure a particular social phenomenon.

2.2. Research Participants
The research participants consisted of 54 eleventh graders from two public senior high schools in Malang, SMA Negeri 3 and SMA Negeri 7. Based on the results of an equality test, the former was assigned as the representative of students with high academic ability while the latter was appointed to represent students with low academic ability.

2.3. Data Collection Procedures
The research data were collected randomly using an essay test which was developed on topics related to Virus. The students’ responses were evaluated based on a rubric adapted from Hazeltine 2017. Prior to the examination, the instrument was validated (content validity and construct validity). The students’ argumentation skills were scored 1-4. Each of the categories can be explained as follows: score (1) indicated that the students’ argumentation skills were undeveloped, score (2) indicated that the students’ argumentation skills started to develop, score (3) indicated that the students’ argumentation skills were developing, and score (4) indicated that the students’ argumentation skills were well developed. An unpaired t-test was used to investigate the difference between male and female students’ argumentation skills.
3. Findings and Discussion
The results of the t-test showed a significant difference between low and high abilities students’ argumentation skills (significance level of 0,003). The students’ argumentation scores were depicted in Table 1.

| Levene’s Test for Equality of Variances | t-test for Equality of Means |
|----------------------------------------|-----------------------------|
| F          | Sig. | t   | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference |
| Equal variances assumed | 9.153 | .004 | 3.125 | 52 | .003 | 2.59448 | .83015 | .92867 | 4.26030 |
| Equal variances not assumed | 3.255 | 44.542 | .002 | 2.59448 | .79701 | .98876 | 4.20021 |

Students with higher academic ability could successfully reach level 1 argumentation skills with a percentage of 10,34%, level 2 with a percentage of 74,41%, and level 3 with a percentage of 17,24%. On the other hand, only 12% of the students with lower academic ability reported level 1 argumentation skills and 88% of them reported level 2 argumentation skills. The students’ argumentation skills were summarized in Table 2.

| Level | Percentages |
|-------|-------------|
| High Ability | Low Ability |
| Level 4 (very high, very well improved) | 0% | 0% |
| Level 3 (high, needs improvements) | 17,24% | 0% |
| Level 2 (adequate, being improved) | 74,41% | 12% |
| Level 1 (poor, not well improved) | 10,34% | 88% |

3.1. The Students’ Scientific Argumentation Skills Based on Differences in Academic Abilities
The results of the current research revealed that none of the high ability students could reach level 4 argumentation skills. The highest percentage was observed in level 2 (74,41%), followed by level 3 (17,24%), and the lowest percentage was reported by level 1 (10,34%). Similarly, the low ability students reported the highest percentage in level 2 (12%) while the rest of the students were categorized in level 1 and none of the students were observed to have very well improved argumentation skills (level 3 and level 4).

The differences between the high and low ability students’ argumentation skills are strongly connected to their thinking abilities. Since changes were brought to the national recruitment system (based on the Minimum Passing Level National Exam (MPL NE) [18], people have been introduced to the high ability and low ability students. Therefore, many studies were conducted and the results have shown that high ability students are able to perform better at higher order thinking compared to the low ability students [19,20]. High ability students are fast learners [21]. They have a good long-term memory which has an impact on their excellent learning achievement [22] and higher order thinking skills [23].
Learners with high academic ability look more focused and active and are more responsible for their own reading and learning activities while learners with low academic ability are easily distracted and discouraged. Research has shown that students’ academic abilities may influence the way students deliver arguments. Students with high academic ability have better argumentation skills than students with the low academic ability [24], because high ability students are more skillful in collecting data and evidence. They are also capable of communicating the results [25,26].

On the other hand, low ability students are lacking in the ability to collect data and information [26]. Therefore, it is difficult for them to follow Toulmin’s argumentation model which includes claims (conclusions, propositions, or statements), data (evidence supporting claims), evidence (explanation of the relationship between claims and data), support (basic assumptions that support evidence), qualifications (conditions that the claim is true), and refutation (the condition that aborts the claim) [27] to justify their arguments. Scientific argumentation can help increase students’ knowledge of a concept, involvement in scientific work, and literacy [9].

The students’ poor performance in argumentation skills may also result from the unavailability of learning materials that can improve students’ thinking skills. As a matter of fact, learning is dominated by activities that do not accommodate students’ higher order thinking and argumentation skills. Habitual argumentative dialogues can promote students’ argumentation skills [28]. Therefore, appropriate learning materials accompanied by an innovative learning model can eventually empower students’ argumentation skills.

3.2. The Students’ Scientific Argumentation Skills Based on Toulmin’s Indicators

Toulmin Argumentation Pattern (TAP) is very applicable for research which aims to identify arguments and measure the quality of the argumentation [25]. There are six important elements of an argument according to Toulmin. They are claims, grounds, warrants, qualifiers, backing, and rebuttals. Claims appear in the form of statements that are raised and accepted as true. Claims become central in a text. Claims will always be clarified and maintained by grounds or data which serve as the foundation to strengthen the claims. If the evidence to support a claim is insufficient, a guarantee or a warrant can be presented. A warrant is a statement that links a claim with data. The presence of claims, data, and warrants indicates a well-structured argument. The supporting evidence for warrants is called backing. When a claim contains certain possibilities, a qualifier can be offered [27].

Followings are the examples of the test questions and the students’ answers to the problems.

Wiwin is a 5th-semester biology student doing research on ecosystems in a forest. He went to a Community Service Program with 15 friends, spending one week in the forest. After leaving the forest, the group experienced serious illness, except Wiwin. After a blood test, they were positively infected with the Zika virus transmitted by *Aedes aegypti* mosquitoes. Wiwin also took a blood test. The results of Wiwin blood test were negative (not infected with Zika virus). Wiwin had ever caught a contracted dengue fever when he was 15 years old. Based on the case, answer the following questions.

How is Zika virus transmitted? Give an explanation regarding the phenomenon. Why did the Zika virus infect more than one person?

Level 1 Answer:

Zika virus can be transmitted to humans by *Aedes aegypti* mosquitoes (claim). The virus will spread to the patient’s body through the circulation system (warrant). If the immune system is weak, the virus can easily infect humans (backing). Infection does not stop at one person because Zika virus can easily spread and affect humans (claim). However, if you have a strong immune system, you cannot be attacked by the virus (backing).

The student had proposed a correct claim and a warrant that could support the claim “Zika virus can be transmitted to humans by *Aedes aegypti* mosquitoes”. However, the student had not provided the backing that was relevant to the statement. He did not explain ground or data so that he could not justify his argument.
The “Infection does not stop in one person because Zika virus can easily spread and affect humans” statement was considered as a partly correct claim. There was no backing, data, ground, or rebuttal. This student’s response indicated that the student’s argumentation skills had not been empowered.

Level 2 Answer:
Zika virus transmission is caused by Aedes aegypti mosquitoes (claim). Aedes aegypti mosquito is a vector of transmission of the Zika virus, and the virus can spread through the circulation system (Warrant). Virus infection can spread rapidly in human’s body if the body's defense system is weak (backing). Infection does not stop at one person because there are many Aedes aegypti mosquitoes living in nature, biting many people and let the infection persist (claim). Mosquitoes can also move from one place to another, so Zika virus can infect many people (backing).

In the students’ response, the claim was delivered correctly. The student also supported the claim with warrant and backing but failed to provide ground or data so that the argument was considered weak. The next answer indicated a correct claim and appropriate backing but it did not contain any data, ground, or rebuttal. It suggested that the student’s argumentation skills were being developed.

Level 3 Answer:
Zika virus is carried out by Aedes aegypti (claim). Aedes aegypti is the transmission vector of the virus. The virus spreads in the human’s body through the circulation system (warrant). The virus will infect the body easily if the body's defense system is weak (backing). Infection does not stop at one person because Aedes aegypti mosquitoes bite many people (claim). In the human’s body, the Zika virus will reproduce so that the number of the virus is multiplied. The transmission is also caused by migration; thus, it can be found anywhere (backing).

The student had successfully mentioned a correct claim and provided strong warrant and backing, but failed to provide ground or data. As a result, the argument was considered weak. The other response following the first indicated that the claim was right. There were warrant and backing provided to support the claim; however, there was no supporting data, ground, or rebuttal. It thus suggested that the student’s argumentation skills were still at the “need improvements” stage.

The students’ responses showed various levels of argumentation skills (level 1 to level 3) that still needed improvements. The students’ poor performance in argumentation skills might be caused by several factors. One of which is because the students were not given an opportunity to get involved in scientific argumentation activities in the classroom. Many students can identify a problem and a solution to it but fail to prove that the solution is the best because they cannot offer strong understanding, reasoning, and arguments. The students might misunderstand a concept since they cannot collect logical evidence and reasons. Scientific argumentation skills are useful in science learning because they can generate a generation with scientific soul and justify knowledge through statements, beliefs, and actions [29]. Arguments must be proven; therefore, learners need to learn how to demonstrate the truth by concrete evidence [30]. The evidence will also help students in solving a more difficult problem in the future [31].

A study has unveiled that Indonesian students have a tendency to focus on empowering claims without empowering other elements of argumentation skills. Consequently, the students acquire a poor understanding of some learning concepts. The empowerment of students’ argumentation skills as a whole will result in broadening the students’ comprehension of particular concepts [32]. Therefore, learning should be focused on how to engage students actively in the process [33].

3.3. Promoting Students’ Argumentation Skills through Learning Models
The problem-based learning model is an alternative to improve students’ scientific argumentation skills. The main characteristics of problem-based learning include the submission of questions or problems, the focus on interdisciplinary studies, authentic inquiry, production and exhibition, and collaboration [34]. Research has shown that problem-based learning can improve students’ critical thinking skills, creative thinking skills, problem-solving skills and scientific argumentation skills [35,33].
Problem-based learning allows students to be aware of the abilities to learn to use knowledge operationally and do group work in a real-world context [36]. The five characteristics of problem-based learning are the submission of questions or problems, the focus on interdisciplinary studies, authentic inquiry, production and exhibition, and collaboration [37]. Some problem-based learning models have been proven effective to improve students’ critical thinking skills, creative thinking skills [35], and argumentation skills despite the differences in the students’ academic levels [26]. One of the examples of the effective learning models is RICOSRE of which syntax consisted of reading, identifying a problem, constructing a solution, solving the problem, reviewing the solution, and extending the problem-solving activity [35].

4. Conclusions
The results of the present research have indicated that the majority of senior high school students in Malang have a poor performance in argumentation. In other words, their argumentation skills need a lot of improvements. It has also been reported that there is a difference between high and low ability students’ scientific argumentation skills. The average score achieved by the high ability students was significantly higher than that obtained by the low achievers. The most appropriate solution to improve students’ scientific argumentation skills is to implement an innovative learning model in the classroom. RICOSRE is a problem-based learning model that can be used as one of the alternatives to empower students’ scientific argumentation skills.

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