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# Exploring the Argumentation Level in Inquiry Learning of Force and Motion

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***Abstract*** **–** One of the learning methods that is proven to be able to develop and improve students' critical thinking skills is to apply an argumentation strategy with ADI (Argumentation-Driven-Inquiry). This study aims to investigate the level of student argumentation on the subject of motion and force. This study focused on identifying the level of student argumentation after the ADI model was applied. The research population was students of Physics Education, Surabaya State University, whose year class is 2020. The sample selection used a random sampling cluster technique. The used instrument consisted of a multiple-choice test with 10 questions and 2 essays to determine the level of student argumentation. The results showed that the students' arguments were at level 3, namely the ability to analyse problems related to motion and force. Based on the results of the study, it can be concluded that the argumentation abilities of students who do not contribute to give argumentation or who are at level 1, are not able to answer analytical questions about motion and force phenomena properly. Meanwhile, students who are at level 2 are still fixated on one concept or method, and still have difficulty when trying to apply other methods to solve problems. Students whose argumentation are at level 3, 4, and 5 have been able to fulfil all the characteristics of critical thinking, but some still have weaknesses, namely the ability to analyse motion and force problems.

**Keywords:** *Argumentation, Inquiry, Force, Motion*

***Abstrak*** **–** *Salah satu metode pembelajaran yang terbukti mampu mengembangkan dan meningkatkan kemampuan berpikir kritis siswa adalah dengan menerapkan strategi argumentasi dengan ADI (Argumentation-Driven-Inquiry). Penelitian ini bertujuan untuk mengetahui tingkat argumentasi siswa pada materi gerak dan gaya. Penelitian ini difokuskan untuk mengidentifikasi tingkat argumentasi siswa setelah model ADI diterapkan. Populasi penelitian adalah mahasiswa Pendidikan Fisika Universitas Negeri Surabaya angkatan 2020. Pemilihan sampel menggunakan teknik cluster random sampling. Instrumen yang digunakan terdiri dari tes pilihan ganda dengan 10 soal dan 2 essay untuk mengetahui tingkat argumentasi siswa. Hasil penelitian menunjukkan bahwa argumentasi siswa berada pada level 3 yaitu kemampuan menganalisis soal-soal yang berkaitan dengan gerak dan gaya. Berdasarkan hasil penelitian dapat disimpulkan bahwa kemampuan argumentasi siswa yang tidak berkontribusi dalam memberikan argumentasi atau yang berada pada level 1, tidak mampu menjawab pertanyaan analitis tentang fenomena gerak dan gaya dengan baik. Sedangkan siswa yang berada pada level 2 masih terpaku pada satu konsep atau metode, dan masih mengalami kesulitan ketika mencoba menerapkan metode lain untuk menyelesaikan masalah. Siswa yang argumentasinya berada pada level 3, 4, dan 5 sudah dapat memenuhi semua ciri berpikir kritis, namun beberapa masih memiliki kelemahan yaitu kemampuan menganalisis soal gerak dan gaya.*



**Kata Kunci:** *Argumentasi, Inkuiri, Gaya, Gerak*

# 1. Introduction

Several researchers have shown that students do not have a clear understanding of Newton's laws [1]. Some students have understood that force is the cause of motion. Their misunderstanding (misconception) about the relationship between force and motion is evidence that their common sense is resistant to change. It is very important for students to fight the resistance of misunderstandings about the relationship between force and motion. Newton's laws in many textbooks for high school level are treated so abstractly and students cannot reach an understanding of Newtonian principles of the relationship between force and motion. If the discussion of all types of motion is carried out through Newton's second law, and not as separate parts, then the understanding of attitudes, knowledge and skills of students is believed to increase.

The main part of mechanics is the discussion of the motion conditions of a mechanical system through the coordinates determination with respect to time. The solution to this condition is determined when the initial state of the particle's motion is known and when the properties of the force are known as a function of the particle's coordinates. Through setting the initial forces and conditions for the position of the particle in the differential equation of Newton's second law and solving the equation for Newton's second law, we can describe how changes in physical quantities are related as a function of time.

Students' ability to make arguments often cannot be developed because some lecturers who teach do not provide opportunities for students to provide opinions on the knowledge they have acquired or provided in science learning [2]. So that students only receive an explanation from the teacher without commenting whether what is given is the correct explanation or less accurate information. The result is that students' argumentation skills are not explored. Argumentation skills also depend on the characteristics of the students themselves. These characteristics can be seen clearly in the cognitive abilities of students at the level of low achievement, medium achievement, and high achievement. This is very important to study because students' abilities can influence how students present their arguments. As research from several researchers who said that the academic level of students was obtained from the results of their past academic tests and could affect how they conveyed their arguments, motivation, and higher order thinking [3] This study differs from others in that the development of students at the academic level is only a by-product, not as a result and the main focus on the problem [4], and also with learning the ADI model, but not in learning. integrated with science, they only conduct research in the fields of Physics, Biology, Chemistry, or other fields [5]. To overcome this problem, the ability to argue can be practiced in science learning in order to improve and develop the argumentation skills of students with different academic levels. One way to practice these argumentation skills is to apply an argumentation-based learning model, namely Argument-Driven Inquiry (ADI). ADI can improve students' argumentation skills. In line with research that has been carried out by several researchers with the same results, the ADI learning model in science learning can improve argumentation skills [6] [7].

Students are familiar with Newton's I, II and III Laws because they have learned about them from Middle School or High School. Most of them can memorize those Newton's Laws and can say every word of Newton's Laws. Indeed, there is no difficulty in formulating Newton's first law**,** $\boldsymbol{F}$=0, Newton's second law of motion and applying simple equations: $\boldsymbol{F} = ma$ as well as Newton's third law, action force = -reaction force. However, they do not have a clear and correct understanding of Newton's laws. This is because students have concepts that they consider reasonable about motion and in most cases, they took a long time to change understanding, for example understanding the Aristotelian concept of motion to Galileo's concept which believed that force changes due to motion, for example, that the net force required to keep an object moving at a constant speed [8] [9].

Motion and force are part of science that requires students to have some special skills, where these skills not only include skills related to physical, but also related to skills in thinking such as scientific, critical and creative thinking skills [10] suggest that critical thinking aims to analyse arguments and generate insight into each meaning and interpretation, to develop cohesive and logical reasoning patterns, to understand the assumptions and biases that underlie each position. Students' arguments are categorized into Levels 1–5 based on the included argument components as described by Toulmin (1958) [22]. The student's argument is coded as Level 1 if it includes only the claim. Level 2 arguments include claims supported by data/warrants. Level 3 arguments consist of claims supported by data and/or warrants, as well as with supports that provide additional information to support data/warrants or qualifications that explain the conditions under which the claim is true. The highest argument level or level 4 represents the most sophisticated argument and includes claims, data/warrants, endorsements, and qualifications [3]. This model will create several different arguments, the different arguments will be categorized/grouped based on their respective levels [10] [11]. The argumentation levels will be grouped using Toulmin's arguments, where there are level 1 (claims), level 2 (claims and data), level 3 (claims, data and backing/solutions) and level 4 (claims, data, backing/solutions, and qualifications). Several studies have identified the effect of argumentation on conceptual understanding [2] [3] [23] [21] and to identify students' level of argumentation [14] [13]. This study aims to investigate the level of student's argumentation on the subject of motion and force. The research focused on identifying the level of student's argumentation after the ADI (argumentation-driven-Inquiry) model was applied.

## 2. Methods

The research methods used and described in this manuscript are mainly based on the use of qualitative tools. Several qualitative findings were analysed quantitatively. A qualitative approach allows us to describe in detail the phenomena and processes that occur in the laboratory and are associated with building an argument. Quantitative analysis of the qualitative findings allows us to describe the magnitude of the phenomena we identify. This research includes qualitative analysis research, the subjects of this research are 2 lecturers, 2 experts as observers and 25 students of the superior class of the physics education study program, State University of Surabaya.

The open inquiry experiments include: Students conduct open-type inquiry experiments in which they are exposed to a phenomena of motion and force; they ask questions about it, select research questions, write hypotheses related to the research questions, plan experiments to test their hypotheses, and then conduct experiments using computer simulations (SKGG) which can be accessed at google.com/drive/folders/1j0mj8sGcYWOCVTU0NogvQZ5Sl5fKc4KZ?usp=sharing, then they organize their results and draw conclusions, then analyse and summary the inquiry experiments. This SKGG is the result of research by.

Laboratory observations were carried out during laboratory sessions and focused on discourse related to experiments that occurred during computer simulation learning activities when students conducted experiments. The discourse was recorded using audio and parts of the laboratory activities formulated rational hypotheses, analyse the results, and draw conclusions. This section includes interactions between group members, and sometimes interactions between group members and the lecturer, who approaches and interacts with them [13]. Discourse is analysed according to the following criteria: basic argument components: claims, evidence, and scientific explanations. The analysis to identify the components of the argument was carried out using the Toulmin model [22].

The data collection in this study used an observation sheet that contains elements of argumentation skills, which are equipped with an argumentation skill assessment rubric. The used instrument consisted of a multiple choice test with 10 questions accompanied by reasons and evidence or data and 2 essays to determine the level of student's argumentation. Observations focused on the production of student argumentative elements, especially on claims including counter arguments and rebuttal for 2 hours of learning in 4 meetings with the help of motion and force computer simulations (SKGG) during the learning process.

In this study, the raised material is motion and force with the indicator that students analyse the relationship between forces, mass, time, and acceleration of objects on the regular straight motion and regular accelerated straight motion on a flat plane accompanied by the reasons. The data collection method is done by grouping the level of student's argumentation based on the level of Toulmin's argumentation through a post-test. The identification of the argumentation level follows the indicators that have been analysed by the author which is a combination of the argumentation level indicators [13].

# 3. Results and Discussion

Identification of Student's Argument Level are varied, most of the students only gave claims without any justification/proof and were at level 1, and a few who gave claims with evidence were at level 2. The first question had not yet reached the argumentation level 3, 4 and 5. In the second and third questions, the results were better than the first meeting, students were more active, and some students who had not previously participated also gave statements. This is in line with previous research that students tend to make claims without data [14]. The level of student's argumentation is grouped based on the level of argumentation by Toulmin [22]. Examples of the research data are shown in Table 1.

The main weakness found in the way students argued was the inability to identify data related to the stated conclusions. Students are fixated to only actively discuss without considering the suitability of their claims with existing data (theories and facts), and the suitability of the topic being discussed. The consequence of this is that their argument are considered weak, and is not valid, nor relevant.

**Table 1.** The levels of the arguments posed by the students

| The components | Symbol | level | Examples of arguments at different levels |
|---|---|---|---|
| Claim | C | 1 | Student 1: To keep an object moving in a straight line on a very smooth surface at a constant speed, the magnitude and direction of the force acting on the object must be constant. |
| Claim + Data or | CD CW | 2 | Student 2: The magnitude and direction of a constant force will not produce acceleration or deceleration, so the object is moving in a straight line with constant velocity. |
| Claim + Data + Warrant | CDW | 3 | Student 3: When we simulate using SKGG and we keep the force 0, the object's acceleration is also 0. |
| Claim + Data + Warant + backing | CDWB | 4 | Student 4: I would like to state that regardless of the speed of an object moving in a straight line on a very smooth surface at a constant speed, the velocity of the object will remain constant if the force acting on the object is large and in a constant direction. He drew a graph of force vs. time, where force is a straight line over time for constant velocity. |
| Rebuttal that Includes Claim + Data + Warrant | CDWR | 5 | Student 5: The object will stop because there is no acceleration of the object.<br><br>Student 6: Your statement is wrong. Objects can still move in a straight line or move at a constant speed, even if there is no acceleration. |

Based on the data in Table 1, students who have a low level of argumentation (level 1), their critical thinking ability is at level 1 which indicates that students are only able to distinguish relevant and irrelevant information, in other words, these students only know the concepts that have been taught but do not understand the concept. This is in line with research [2] where students who do not understand the concept are unable to distinguish between true and false statements so that it is difficult to prove claims. Students who have a moderate level of argumentation (level 2), their critical thinking skills are at level 2 and level 3, which is quite critical, meaning that students are able to understand the concept well and understand the characteristics of a certain thing even though it has been changed in shape but has not been able to draw conclusions after all the facts have been collected and considered. Students tend to be wrong in concluding. Meanwhile, students whose argumentation skills are at levels 3, 4 and 5 are proven to be critical, but especially students at level 3 are less able to break down complex problems into new simpler parts to find simpler solutions. Other studies have also found a lack of rebuttal in student arguments [14].

Broadly speaking, the level of student argumentation is closely related to their level of critical thinking. The results of previous studies also stated that argument instruction contributed to higher-order thinking skills [4]. When a student is able to issue a claim that is supported by some data obtained from the identification of existing facts and several supporting theories, the student is categorized as critical.

The level of argumentation submitted by students is presented in Table 1. The two main aspects referred to are: (1) the components that form the basis of the argument (proof of claims and scientific explanations), and (2) the existence of rebuttals or counterclaims. When the argument includes multiple components, the level is higher. Arguments at level 3 include the classic elements of an argument: claims, evidence, and scientific explanations that relate to them. On the other hand, during argumentative discourse, there is an additional dimension which includes counterclaim or refutation, the presence of which serves as evidence of a high level of argumentative discourse. Consequently, this element is taken into account when determining the level of argumentation. The highest level of argumentation, level 5, includes evidence-based rebuttals and the accompanying scientific explanations. Discourse analysis was validated by 2 experts. Note that during the argumentation component analysis, we use scientific explanatory expressions rather than commands because students tend to explain the evidence supporting their arguments using scientific explanations based on their prior knowledge of motion and force content.

The discourse during the experiment was transcribed, and used for two additional purposes: (1) Finding evidence of student shrewdness to explain their arguments, and (2) tracking student questions during dialogue. The experiments conducted by students are categorized according to the following criteria: (1) simple/complex experiments, and (2) experiments in which students obtain results that match or do not match the proposed hypothesis. An experiment was defined as complex based on the above criteria, i.e. consisting one of the following: The experiment was not in harmony with the concepts or topics taught at that time in motion and force classes, and/or was based on a scientific background that was not part of the curriculum.

During the experiment using the SKGG, students were involved in various inquiry skills such as formulating hypotheses, analysing results, and drawing conclusions, which were categorized as higher order thinking skills. We found some evidence in the discourse for students' awareness of task requirements. A discussion between two students would be an example (among many others). One student stated: We discussed our hypotheses, and even wrote them in our report. His partner replied: “That's not enough! In the instructions it is written that we need to give reason and explain each hypothesis.” Even from the minor episodes above, we can conclude that students develop an awareness of task requirements and instructions.

In the experiments observed during open inquiry experiments using the SKGG computer simulation, students were indeed given a platform to build arguments, both as individuals and as part of a group. This is the result of a special feature of this learning environment: working in small groups which allows students to conduct argumentative discourse. This includes the need to provide explanations for observed phenomena, select inquiry questions, formulate hypotheses, provide results and draw conclusions, and initiate group discussion while arguments are presented. Arguments are based on evidence gathered during the experiment and are usually based on scientific explanations learned in class or on knowledge gathered during group discussions about concepts that is not learned in class. Furthermore, students allocated time to do all these things so that their potential can be utilized [13] [17].

We have found two factors that influence the existence and extent of argumentative discourse when conducting open inquiry experiments. The first is the task requirements and the reason for the assessment of the task. Students know the reasons and requirements of the assignment. Strict work instructions for students and assessment indicators determine the implementation of inquiry activities in the laboratory. There is evidence in group discourse for this argument. Students read the instructions seriously and carry out the activities step by step. They also check the compatibility of their implementation with the indicated requirements. This awareness is the result of the inculcation of skills and work habits by lecturers, which is also revealed in the discourse [13].

One of the goals of science is to provide opportunities for students to build an understanding of natural phenomena that are broader in scope, scientific concepts and principles of science are very important in the application of daily life activities every day. The implementation of science learning in the classroom is not only limited to accepting the concepts given by the lecturer but students are able to find the concept itself as a result of the discovery process and students' higher thinking levels can be trained. One of the skills that can be developed to achieve quality education to build scientific concepts and train students' higher-order thinking levels is argumentation skills. Argumentation skills in the science learning process are needed for concept development and practicing ways of thinking about a concept so that students can find facts, concepts and other things related to all sciences and stored in students' long-term memory. On the other hand, argumentation is important in science learning because science is not only presenting facts but building arguments, considering, debating various scientific phenomena [19].

## 4. Conclusion

Based on the results of the study, it can be concluded that the argumentative abilities of students who do not contribute to give arguments or who are at level 1 are not able to answer analytical questions about motion and force phenomena properly. Meanwhile, students who are at level 2 are still fixated on one concept or method, and still have difficulty trying to apply other methods to solve problems. Student whose argumentation level are at level 3, 4, and 5 have been able to fulfil all the characteristics of critical thinking, but some are still have weaknesses, namely the ability to analyse motion and force problems. Students are less able to break down complex problems into new, simpler parts to find simpler solutions.

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