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Exploration of Argumentation and Scientific Reasoning Ability in Phenomenon-Based Argument-Driven Inquiry Learning in Newton's Law Material

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Abstract: The ability of argumentation and scientific reasoning is part of scientific literacy which is a requirement for learning science. Students get knowledge according to the understanding of scientists, which is important for students to have, especially in Newton's law material, but learning in the classroom currently has not developed argumentation and scientific reasoning skills properly. This study used a mixed method design with an embedded experimental design carried out offline. This research design was used in order to obtain an in-depth picture of students' argumentation and scientific reasoning abilities. The results showed that students' argumentation and scientific reasoning abilities increased significantly after being given the phenomenon-based Argument-Driven Inquiry (ADI) learning model. This learning has a moderate effect on argumentation skills and a very large one on students' scientific reasoning. Even though students' argumentation abilities have increased significantly, on average students still have difficulty in associating a phenomenon with the appropriate Newton's Laws. Scientific reasoning students also experience positive changes. This is evidenced by the increase in post-test scores and effect sizes which are in the very large category.

Keywords: Argument-Driven; Inquiry based on phenomena; Newton's Laws; Scientific reasoning

Introduction

Education in Indonesia is currently expected to be able to apply the 2013 curriculum using a scientific approach, namely students learn through observing, asking, trying, reasoning, communicating, and creating. Thus the activity of reasoning is the ability needed by students. Reasoning is a very important ability in the learning process because it can make students think abstractly (Wijaya, 2016).

Reasoning ability is a thinking process that links several concepts so that a conclusion is reached as a new statement (Effendy et al., 2018). Scientific reasoning or scientific reasoning is the ability to think cognitively which includes minds-on and hands-on activities to support the physics learning process (Lazonder et al., 2021; Schlatter et al., 2021; Zimmerman, 2005).

Scientific reasoning needs to be developed so that students have the ability to solve everyday life problems through learning physics (Effendy et al., 2018). In fact, the scientific reasoning ability of high school students in Palembang city reached a score of 30.44%, which is included in the low category (Effendy et al., 2018). Research conducted Khoirina et al. (2018) also shows students' scientific reasoning abilities are in the low category with a value of 33.43%. Students experience errors in doing scientific reasoning and students' abilities are still at the level of remembering (Erlina et al., 2018).

Students' scientific reasoning abilities are influenced by the learning model applied by the teacher in the classroom, therefore an appropriate learning model is needed to train students' scientific reasoning abilities. Scientific reasoning involves the process of

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inquiry and inquiry activities in studying a phenomenon (Zimmerman, 2005).

When doing scientific reasoning students connect and investigate facts or phenomena to support arguments (Erlina et al., 2018). Structured scientific reasoning skills can form arguments in the form of conclusions, statements, and explanations of why a phenomenon occurs. Argumentation skills are built based on facts and scientific reasoning (Hsu et al., 2015; Songsil et al., 2019; Zhai et al., 2023).

Kemampuan argumentasi merupakan salah satu form of communication activity. In implementing the 2013 curriculum through a scientific approach students are required to have communication skills (Fadhilaturrahmi, 2017; Pebriani et al., 2020). Argumentation is an important skill that must be taught and learned as a form of scientific inquiry and literacy (Erduran et al., 2015). Argumentation is one of the core activities that must be carried out by students with teacher guidance in the learning process (Mao et al., 2018). Interpreting phenomena, evaluating the relationship between knowledge, and interpretation with knowledge is the essence of argumentation (Demircioglu & Ucar, 2015). So argumentation plays an important role in the explanation and origins of theory creation. Several components that build argumentation skills, namely The Claim in the form of explanations to answer several questions are strengthened by Evidence. Evidence is a phenomenon resulting from observation or measurement. Reasoning explains how and why the evidence relates as support (Sampson & Gleim, 2009). Based on the Toulmin Argumentation Pattern (TAP) the argumentation component consists of Data, Claims, Warrants, Qualifiers, Rebuttals, and Backing (Erduran et al., 2015).

Expressing arguments based on phenomena can trigger students to have new knowledge. Physics phenomena that are studied in class as materials for presenting arguments so that the inventors get the concept. Students are expected to find new concepts like scientists who find new concepts based on phenomena that are solved through argumentation. Argumentation is an activity of expressing statements supported by data and based on prior knowledge that students already have (Erduran et al., 2015). While involved in the argumentation process, students learn to make statements, use data that supports these statements, and prove statements according to rules or scientific evidence. (Demircioğlu & Ucar, 2012).

Measuring argumentation ability is an important research topic, because it is a competency that students must possess (Deng & Wang, 2017). In recent years a lot of research has been conducted to measure students' argumentation abilities, but this research has not directed students to develop phenomenon-based argumentation skills (Faize et al., 2017; Osborne et al., 2019; Syerliana et al., 2018).

The argumentation ability of high school students is still relatively low (Rahman et al., 2018). On the topic of kinematics, the ability of physics teacher candidates in giving arguments is quite good, but the concepts used to support arguments are still not quite right (Ain et al., 2018). On the topic of Newton's Laws, students still experience difficulties in giving arguments (Wardani et al., 2018). Newton's laws have an important role in studying physics (Coletta et al., 2019) because it can explain the phenomena that exist in everyday life (Srisawasdi & Sornkhatha, 2014).

Newton's law is a physics topic that studies the relationship between internal forces acting on objects and external forces exerted on objects causing objects to move (Giancoli, 2014; Serway & Jewett, 2004). Newton's law is a fundamental topic that is considered difficult by students. Students find it difficult to understand Newton's First Law, for example when on a stationary object students assume that gravitational forces always act on objects but do not understand the existence of a normal force, in Newton's Second Law students assume that if the resultant force acting on an object is not zero then the object moves in a straight line, and in Newton's Third Law some students have the understanding that the gravitational force is an action reaction with a normal force (Aviani et al., 2015). Research that has been done Smith & Wittmann (2008), in Newton's First Law students assume that force is always needed to maintain the motion of objects, in Newton's Second Law students assume that the force acting on an object is proportional to the speed, and in Newton's Third Law students assume that when colliding objects that have greater speed give greater force . The existence of students' difficulties on the topic of Newton's Laws causes low students' argumentation skills (Rahman et al., 2018; Wardani et al., 2018). Students need help developing scientific reasoning and argumentation skills to achieve competency according to the 2013 curriculum. One model that can develop argumentation skills is Argument-Driven Inquiry (ADI) (Demirbag & Gunel, 2014; Demircioğlu & Ucar, 2012; Hidayat & Prabawanto, 2018).

Argument-Driven Inquiry (ADI) is a laboratory-based inquiry learning model combined with argumentation so that it can train students to present arguments (Sampson & Gleim, 2009). The results of research on the Argument-Driven Inquiry (ADI) learning model can develop students' argumentation skills and argumentation writing abilities (Sampson et al., 2011), scientific reasoning ability in students' mathematical creativity increases (Hidayat & Prabawanto, 2018), the ability to write and present arguments increased significantly (Demirbag & Gunel, 2014), on the subject of electric magnets the quality of student teachers' argumentation increases significantly (Demircioğlu & Ucar, 2012), in light material there is an increase in the level of student argumentation (Ginanjar et al., 2015). Argument-Driven Inquiry (ADI) with Scaffolding is more effective for developing students' argumentation skills compared to conventional learning (Hasnunidah et al., 2015).

Research on argumentation skills using the Argument-Driven Inquiry (ADI) model has recently been carried out a lot, but research using phenomenon-based Argument-Driven Inquiry (ADI) is still rare. The phenomenon in question is a phenomenon-based learning. . Phenomena are studied as a whole and in depth, in real contexts, and relate them to other knowledge and information. The phenomena used in learning are for example real objects that can be observed (Symeonidis & Schwarz, 2016). There are five dimensions of the phenomenon-based approach, namely holisticity, authenticity, contextuality, problem-based inquiry learning, and learning process. Holisticity is from traditional learning integrated with real phenomena. Authenticity is the method, tools, and materials in accordance with the real world, where the knowledge is applied. Contextuality, students learn real objects that exist in nature. Problem-based inquiry learning, students learn and construct knowledge based on self-asked questions, in phenomenon-based learning students learn by asking questions together. The learning process in phenomenon-based learning is seen as a process that is directed and facilitated from learning tasks. Based on the Toulmin Argumentation Pattern (TAP) in the Data component contains facts and phenomena that are used to support claims (Ain et al., 2018; Erduran et al., 2015) thus the phenomenon is needed to build argumentation skills.

Method

This study used a mixed method with an embedded experimental design carried out offline. The mixed method used consists of two methods, namely quantitative as the main method and qualitative methods as supporting methods. Based on the Embedded Experimental Design the researcher develops a research design as shown in Figure 1.

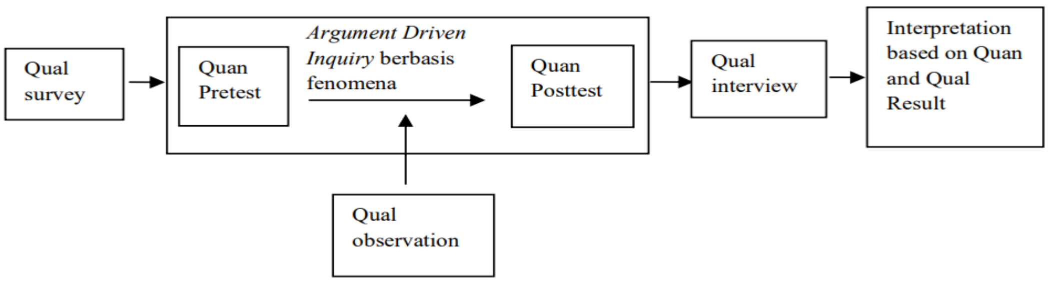

Figure 1. The research design is based on the Embedded Experimental Design

The qualitative research design was carried out by means of a qual survey at the beginning of the research design by conducting short interviews with students to find out their previous learning. The pretest was conducted to measure students' argumentation and scientific reasoning skills about Newton's Laws. The researcher intervened by applying phenomenon-based Argument Driven Inquiry, during the intervention the researcher was observed by observers who already understood Argument-Driven Inquiry, besides that the researcher also observed students' argumentation and scientific reasoning abilities using observation sheets. The posttest is given after learning with a phenomenon-based Argument-Driven Inquiry to measure students' argumentation and scientific reasoning abilities on Newton's Law material.

Quantitative research design with a quasi-experimental one group pretest posttest design was carried out with one experimental class. This design can be seen in Table 1.

Table 1. Research Design

Class	Pretest	Treatmen	Posttest
Experiment	0_1	X	0_2

The increase in students' argumentation and scientific reasoning abilities during the pretest and posttest was tested with N-Gain in the categories as shown in Table 2.

Table 2. Normalized Gain (N-gain) Avarage Criteria

Interval	Criteria
$(g) \geq 0.7$	High
$0.3 \leq (g) \leq 0.7$	Medium
$(g) < 0.3$	Low

Prior to the paired t-test, a prerequisite test was carried out, namely the normality test. If the data is normally distributed, then a paired t-test can be performed. The paired t-test aims to calculate differences in students' argumentation and scientific reasoning skills before and after being given a phenomenon-based argument-driven inquiry lesson.

The power of increasing students' argumentation and scientific reasoning skills before and after learning is measured using the d-effect size (Morgan et al., 2004). The d-effect size value can be calculated using equation 1.

$$d = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{Average}} \quad (1)$$

Information:
d : Effect size Value
$\bar{x}_{post}$: Average post-test scores
$\bar{x}_{pre}$: Average pre-test score
SD Average : The average standard deviation of the pre-test and post-test scores

Table 3. Interpretation of Effect Size Values

Value of Effect Size	Interpretation
≥1	Verry Big
0.80 – 0.99	Big
0.50 – 0.79	Medium
0.20 – 0.49	Small

Result and Discussion

At the beginning of the meeting, Newton's First Law was presented. Before the teacher conveys the core activities, the teacher gives apperception to students by presenting a video of the phenomena of everyday life related to Newton's First Law, namely a person on the bus, where from the phenomena shown in the video can lead to learning objectives. Then the students gave their arguments regarding what happened to the people on the bus when the bus moved and the bus suddenly braked. At this stage the teacher also conveys the learning objectives that are achieved after the lesson is completed. Newton's First Law material is carried out during one meeting with 3 JP lesson hours (120 minutes). At the apperception stage the teacher gives questions about Newton's First Law and shows a video to obtain information about students' prior knowledge.

After being given apperception, then proceed to the task identification stage based on the holisticity dimension, collecting and analyzing data based on authenticity, to producing arguments based on the contextualit dimension. Beginning with the identification of tasks based on the holisticity dimension where the teacher divides students into groups each consisting of 4-5 students to conduct experiments.

In the argument production stage, students do this by providing supporting and rejecting questions. Production of arguments based on the contextuality dimension, then mutually correcting the arguments given by friends in one group then using an assessment sheet. This activity aims to exchange ideas between students in each group and students can learn things that exist in their daily lives by analyzing phenomena from various sources of knowledge they have and can then be processed as a complete, systematic knowledge.

Figure 2. Students carry out an experiment in Newton's First Law

Figure 3. Students make arguments from the experimental results of Newton's First Law

Students' Argumentation Ability with Phenomenon-Based Argument-Driven Inquiry Learning

Quantitative Data

Data was obtained when students completed the pre-test and post-test questions, then scores were obtained from the answers. The essay questions, which are test instruments, are used to measure students' argumentation abilities. Statistical descriptions of the pre-test and post-test scores of students' argumentation abilities are shown in Figure 4.

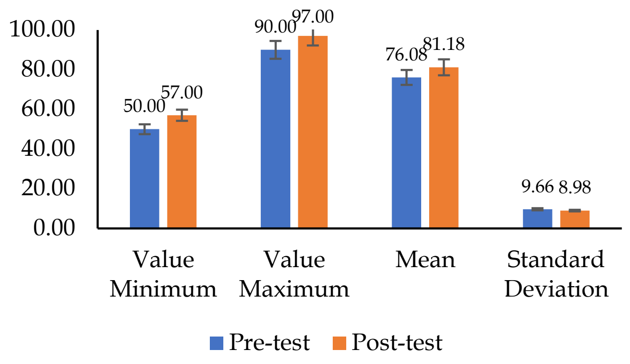

Figure 4. Student Argumentation Ability Data

The results of the normality test using Shapiro Wilk show that the argumentative ability data during the pre-test and post-test has a significance value of > 0.05. Therefore it can be concluded that the data is normally distributed. Then, parametric paired t-test, N-gain and effect size calculations were carried out to determine differences in the value of argumentation abilities during the pre-test and post-test and the effectiveness of the interventions given. The results of the statistical test can be seen in Table 4.

Table 4. Results of Normality Statistical Test, Paired t-test, N-Gain and Effect Size of Argumentation Ability

Statistic test		Score	Criteria
Shapiro Wilk	Pre-test	0.061	Normally distributed
	Post-test	0.163	Normally distributed
Uji-t berpasangan		0.000	Significant
N-gain		0.24	Low
Effect size		0.55	Medium

The results of the paired t-test show a significance value of 0.000 <0.05, thus concluding that there is a significant difference between the pre-test and post-test of argumentation abilities as a result of the intervention. The N-gain value obtained is 0.24 which means that there is an increase in argumentation ability due to intervention in the low category. Furthermore, the effectiveness of the intervention can be seen through the effect size. The effect size value obtained is 0.55 which is in the medium category. This means that the intervention provided in the form of a phenomenon-based Argument-Driven Inquiry (ADI) learning model had an effect on improving students' argumentation abilities on Newton's Law material.

Qualitative Data

Students' argumentation skills at level 1 and level 2A have decreased, this means that there is an increase in students' argumentation skills regarding Newton's Law material after being given phenomenon-based Argument-Driven Inquiry (ADI) learning. So that the number of students who are at levels 1 and 2A decreases because students begin to reach higher levels as shown in Figure 5.

Based on Figure 5 it is known that the number of students who reached the level of student argumentation skills at level 1 and level 2A has decreased, this means that there is an increase in students' argumentation skills regarding Newton's Law material after being given phenomenon-based Argument-Driven Inquiry (ADI) learning. So that the number of students who are at levels 1 and 2A decreases because students begin to reach a higher level.

The ability of scientific argumentation is low because most students answer questions using intuition and verbal language to express reasons for an issue so that the arguments made by students tend to be of low-level argumentation quality and some even do not include reasons at all so that the quality of scientific argumentation cannot be identified. At this level students answer questions using verbal language that has not been proven true. The support used is unfounded, just intuition.

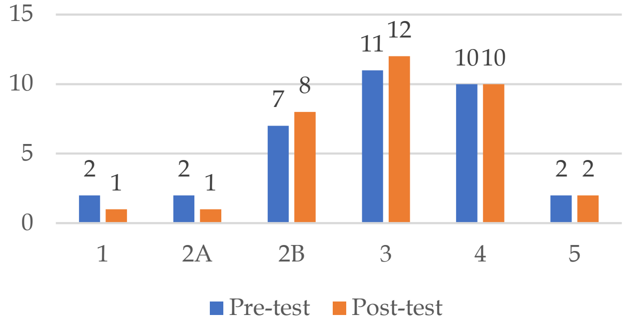

Figure 5. Achievement of Student Argumentation Ability Level

Nearly a third of students, the quality of argumentation is at level 3. Students at level 3 are already able to make reasons supported by data, analyze data without building scientific rules. At this level most students use data analysis and the results of observing an object as a foundation for building support. Students are able to argue using level 3 quality is good enough, and students are expected to be able to upgrade to the next level.

The quality level of the students' argumentation level 4 (ruled-based) remained unchanged. It can be said that students still have difficulty in compiling arguments based on scientific studies (theories, principles, laws). This difficulty is not only felt by students, teachers have the same difficulties (Erduran et al., 2015). This difficulty occurs one of the reasons is the initial knowledge of students. Students incorporate information into their arguments that they have prior knowledge (Faize et al., 2017), participants' understanding of arguments is limited, using reasons they do not understand (Erduran et al., 2015).

Scientific Reasoning of Students with Phenomenon-Based Argument-Driven Inquiry Learning

Quantitative Data Analysis

The data was obtained from the completion scores of students by completing pre-test and post-test questions. The scientific reasoning test instrument is a description question designed to measure students' scientific reasoning. Statistical descriptions of students' pre-test and post-test scientific reasoning scores are presented in Figure 6.

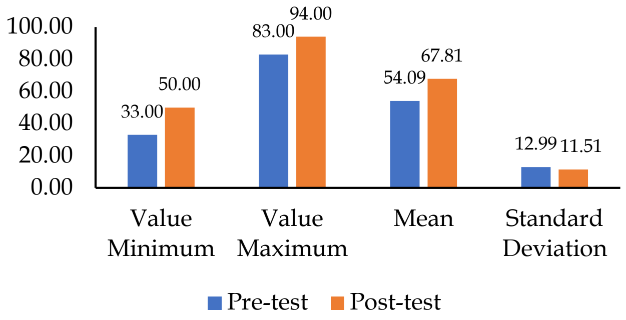

Figure 6. Students' Scientific Reasoning Ability

The results of the normality test using Shapiro Wilk show that the argumentative ability data during the pre-test and post-test has a significance value of > 0.05. Therefore it can be concluded that the data is normally distributed. Then, parametric paired t-test, N-gain and effect size calculations were carried out to determine differences in the value of argumentation abilities during the pre-test and post-test and the effectiveness of the interventions given. The results of the statistical test can be seen in Table 5.

Hasil dari uji-t berpasangan menunjukkan nilai signifikansi 0,000 < 0,05, sehingga memberikan kesimpulan bahwa terdapat perbedaan yang signifikan antara pre-test dan post-test kemampuan argumentasi sebagai dampak dari intervensi. Nilai N-gain yang diperoleh yaitu sebesar 0,46 memberikan makna bahwa terdapat peningkatan scientific reasoning siswa akibat adanya intervensi dalam kategori sedang. Selanjutnya, efektifitas intervensi dapat dilihat melalui effect size. Nilai effect size yang diperoleh yaitu sebesar 3,09 pada kategori sangat besar. Hal ini artinya bahwa intervensi yang diberikan berupa model pembelajaran Argument-Driven Inquiry (ADI) berbasis fenomena memberikan pengaruh sangat besar dalam meningkatkan scientific reasoning siswa pada materi Hukum Newton.

Table 5. Results of Normality Statistical Test, Paired t-test, N-Gain and Effect Size of Students' Scientific Reasoning

Statistic test		Score	Criteria
Shapiro Wilk	Pre-test	0.079	Normally distributed
	Post-test	0.169	Normally distributed
Paired t-test		0.000	Significant
N-gain		0.46	Medium
Effect size		3.09	Very large

Analisis Data Kualitatif

Data diperoleh dari nilai penyelesaian siswa dengan menyelesaikan soal berbasis scientific reasoning. Intrumen tes scientific reasoning yaitu soal uraian yang didesain untuk mengukur scientific reasoning siswa. Soal uraian mengandung keterampilan umum pada suatu eksperimen yang membentuk konsep teori yang mencakup lima pola scientific reasoning yaitu Combinatorial Reasoning, Identification and control of variabels, Probabilistic Reasoning, dan Correlational Reasoning. Selanjutnya, jawaban siswa berdasarkan hasil pre-test dan post-test dianalisis berdasarkan lima pola scientific reasoning tersebut. Persentase hasil perolehan pre-test dan post-test pola scientific reasoning dapat dilihat pada Figure 7.

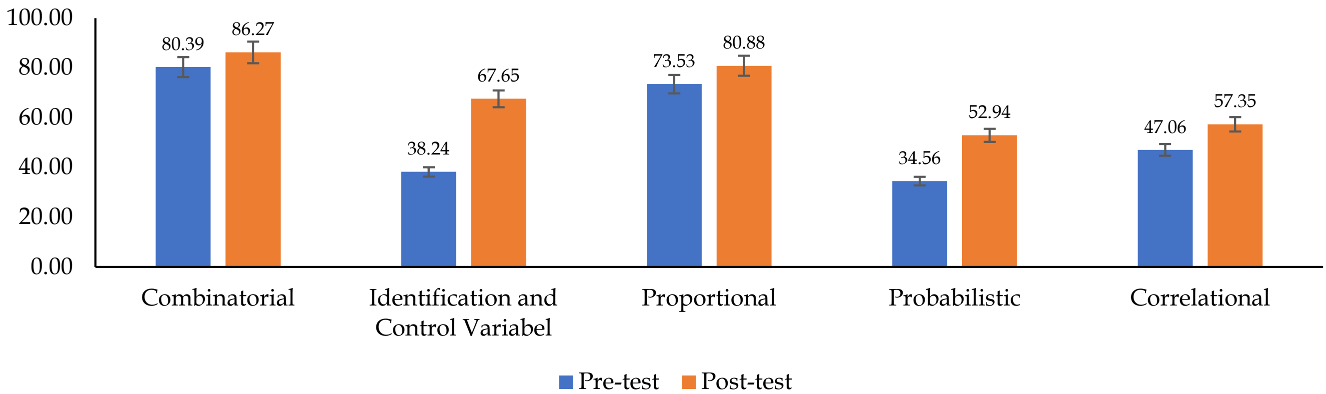

Figure 7. Percentage of pre-test and post-test results with scientific reasoning patterns

Figure 7 shows the increase in pre-test and post-test results on the five scientific reasoning patterns due to the intervention of applying the phenomenon-based Argument-Driven Inquiry (ADI) learning model. There are five items of scientific reasoning in which each item has a different assessment. In the first item with the pattern of scientific reasoning combinatorial reasoning, the second item is the pattern of scientific reasoning identification and control of variables, the third item is the pattern of scientific reasoning proportional reasoning, the fourth item is the pattern of scientific reasoning probabilistic reasoning, and the fifth item is the pattern scientific reasoning correlational reasoning.

Each pattern of scientific reasoning has a different assessment, along with an explanation of the assessment of each item and the results of the students' pre-test and post-test scientific reasoning.

Conclusion

The phenomenon-based ADI research model has an effect on students' argumentation skills on Newton's Law material. This can be seen from the N-gain value of 0.24 in the low category and an effect size of 0.55 in the medium category. After the intervention, students' argumentation skills were at level 1 with 1 student, level 2A with 1 student, level 2B with 8 students, level 3 with 12 students, level 4 with 10 students, and level 5 with 2 students. Thus it can be seen that at level 1 and level 2A there are few students, which means that after the intervention students are able to increase their level of argumentation ability to a higher level. Phenomenon-based ADI learning has an effect on students' scientific reasoning in Newton's Law_matter. This can be seen from the N-gain value of 0.46 in the medium category and the effect size of 3.09 in the very large category. After the intervention of scientific reasoning students in the combinatorial reasoning pattern reached 86.27%, the variable identification and control pattern reached 67.65%, the proportional reasoning pattern reached 80.88%, the probabilistic reasoning pattern reached 52.94%, and the correlational reasoning pattern reached 57 .35%.

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The author is involved in the overall making of this article

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The authors declare no conflict of interest.

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