Enhancing students' scientific argumentation ability on dynamic electric material through analogy and representation-based learning

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ABSTRACT

Introduction. Dynamic electricity is an abstract and complex concept that requires a high level of analysis to solve a problem, so students need to strengthen this concept using analogies and arguments to avoid misunderstandings. *This research aims* to reveal students' scientific argumentation skills through analogy-based learning with a focus on dynamic electricity material.

Study participant and methods. This research used mixed methods with a pre-posttest design involving 74 students in a science education program from one of the state universities in Indonesia. Data was obtained through a dynamic electrical scientific argumentation test in the form of multiple choices, with a Cronbach's Alpha of 0.847, as well as an interview guide regarding analogy-based learning on students' scientific argumentation skills and an argumentation skills rubric. Next, the data obtained was analyzed using the difference test and n-gain.

Results. Our results show that analogy-based learning improves students' scientific argumentation skills with an n-gain of 0.318 (medium) when students perceive the features of a concept and the intercorrelation between concepts. In other words, this learning strategy also makes it easier for students to master and understand the concept of an object. Our findings suggest that students' ability to solve dynamic electrical problems can be accelerated by using appropriate analogies, thereby improving their oral and written argumentation. The majority of students face obstacles in stating data and claims in composing oral and written essays, especially in stating warrants due to students' low initial theory.

Conclusion. Analogy learning is designed to improve students' scientific argumentation skills, especially in dynamic electricity material.

This study found that dynamic electrical learning through the application of analogy and representation, especially by using hand analogy to analogize electrical resistance can significantly improve students' scientific argumentation skills. This approach helps students to analyze complex concepts with the right arguments in answering dynamic electricity problems to be simpler and easier to understand

KEYWORDS

scientific argumentation, dynamic electric material, skill, analogy, learning strategy

For Citation: Rosdiana, L., Parno, Sutopo, & Taufiq, A. (2025). Enhancing students' scientific argumentation ability on dynamic electric material through analogy and representation-based learning. *Perspektivy nauki i obrazovania = Perspectives of Science and Education*, (3), 183–200. https://doi.org/10.32744/pse.2025.3.12

Received: 19 December 2024 | Approved: 12 February 2025 | Published: 30 June 2025

INTRODUCTION

Scientific argumentation skills are a key competency that is very important for students in the 21st century. Scientific argumentation skills are a key competency that is very important for students in the 21st century [1]. In the area of important science, technology, engineering, and math (STEM), scientific argumentation skill is also identified as a key component of deeper learning can be used to solve the complex problems of the 21st century [2]. The development of students’ understanding of key elements within a subject is emphasized as the concept of deeper learning which can be utilized to novel problems and situations inside and outside of school, both individually and in collaboration with others [3]. The study also said that argumentation skills have an impact on students' memory and science process skills, which are an important focus in world education. In an increasingly complex world, these skills not only support academic success, but also become a determining factor for future professional career success [4; 5]. These skills enable students to develop critical thinking, consider multiple points of view, and convey ideas in a systematic and evidence-based manner [6]. Therefore, scientific argumentation skills become the foundation for broader intellectual development and students' readiness to face the challenges of the world of work.

In the context of higher education, scientific argumentation skills are essential, especially for students who will become future science teachers. As future educators, they are required not only to master science materials, but also to be able to communicate and demonstrate scientific concepts to their students effectively. The ability to argue using scientific data and strong evidence is essential in science teaching, especially in developing deep understanding in students [7; 8]. These skills not only support a more effective teaching and learning process but also prepare prospective teachers to stimulate critical thinking in their students [9; 10]. These are the skills that are crucial in preparing the younger generation to thrive in a changing world [11]

Scientific argumentation skills have a crucial role in science learning [12; 13], which often involves complex and abstract concepts, such as dynamic electrical materials. Learning something abstract can give rise to debate, so it requires good scientific argumentation skills. This is because these skills can foster scientific thinking and reasoning [14; 15], ultimately influencing the development of student knowledge [16; 17]. Therefore, developing scientific argumentation skills in the context of science is not only to test understanding, but also to develop effective scientific communication skills.

Although scientific argumentation skills are recognized as an important aspect of science education, research shows that many students, including prospective science teachers, have low scientific argumentation skills [18; 19]. This is due to several factors, including a lack of in-depth understanding of how to build logical and evidence-based arguments, as well as a lack of experience in dealing with situations that require the active use of argumentation skills. In addition, the results of preliminary studies indicate that although there are efforts to integrate scientific argumentation exercises into the curriculum, their effectiveness is often limited by less interactive teaching methods and a lack of strategies that encourage direct student involvement.

Another factor that causes the low quality of students' scientific argumentation skills is often caused by a lack of understanding of abstract and complex scientific concepts, such as those found in dynamic electricity material [20; 21]. Science learning that relies on a theoretical approach without the support of appropriate tools can make it difficult for students to connect theory with real applications [22] In this context, analogy and representation-based learning becomes a very promising alternative to improve scientific argumentation skills. By using relevant visual representations and analogies, it is expected that students can more easily understand difficult concepts, as well as develop better critical thinking and argumentation skills.

Analogy and representation-based learning offers a potential solution to improve students' scientific argumentation skills. Analogy-based learning allows students to relate abstract concepts to more familiar concepts, thus facilitating understanding and strengthening their scientific argumentation skills [23; 24]. Meanwhile, visual representation of science concepts can help students to more easily visualize the relationships between concepts, which is very important in learning dynamic electricity which has an abstract nature [25]. This indicates that these approaches can improve the quality of scientific argumentation by strengthening the link between theory and its application in real contexts.

This study aims to explore and test the effectiveness of analogy-based and representation-based learning, and to dig deeper into how the two strategies can complement each other in enriching the learning process to improve students' scientific argumentation skills in dynamic electricity material. By using an approach that focuses on connecting abstract concepts through more familiar analogies and visual representations, it is expected that students can develop stronger and more structured arguments, and improve their understanding of the topics taught. This study offers a new contribution by integrating innovative learning techniques in the context of higher education, and suggests a more practical and effective approach to improving the quality of scientific argumentation of prospective science teacher students.

Numerous modern devices present a close correlation with dynamic electricity materials, such as electronics, power plants, and sensor devices [26; 27]. Electricity is one of the fundamental fields and topics in physic science as it is extensively applied in human daily life. Electricity is one of the fundamental fields and topics in physic science as it is extensively applied in human daily life [28]. However, this area has been reported to have several concepts in which students develop views that are different from those accepted scientifically [29]. This is attributed to the abstract and complex nature of this concept's system. Meanwhile, this concept is the foundation for students to proceed for further learning [30]. Electricity is one of the fundamental fields and topics in physics because it is widely applied in everyday human life and tends to use informal, intuitive and abstract reasoning rather than rational in understanding in learning. The concept of electricity is abstract and contains a complex system [30; 31]. Different from other materials, observing dynamic electricity through human senses is challenging, such as in examining the electric charges and movement of electric currents [32]. Besides, electric material is identical to the involved processes because it occurs at the atomic level, therefore, this material is abstract in nature [33]. As electricity cannot be identified and seen using personal senses, it cannot be manipulated directly [34].

Due to the nature of electric material, the learning of electricity concepts is complex [35]. A previous study reported that students perceive electricity as more challenging than mechanical materials [36]. The results of the initial survey also suggested that students face issues in the electricity and magnetic course, specifically in the dynamic electricity sub-topic [37]. The concept of electricity, electrical phenomena, and its properties are essential in various levels of physics learning, especially for college students [38]. Further, the issues in understanding the concept of electricity also affect students' scientific argumentation skills [39; 40]. It occurs due to argumentation skills requiring the ability to understand and use the conceptual framework (theories, principles, laws, models, and others), thus, students' low initial concept understanding will obstruct their argumentation skills progression [41].

These problems necessitate immediate solvency. Therefore, we suggest the use of specific strategies in learning. The expected approach improves scientific argumentation skills, as well as facilitates students in learning the dynamic electricity material through analogy representation. The use of this strategy follows the results of the research reporting its efficiency in facilitating students to learn abstract material using the analogy [42; 43]. Another research also uncovers that analogy enables the transformation of complex and abstract material concepts into concrete ones, aiding students to understand them better [44]. Through analogy, teachers can offer objects or ideas with similar or comparable features [45; 46]. Therefore, the analogy-representation helps teachers illustrate abstract and complex electrical concepts (unobserved using the human senses) into concrete and observable ideas.

In addition, scientific argumentation skill is crucial as it assist students in providing reasoning or arguments based on clear facts and truth [47; 45]. This ability is also essential for students' thinking progression using their knowledge and engagement in discussions using scientific evidence for decision-making processes [48; 59]. A previous study [50] has also attempted to increase chemistry student teachers' scientific argumentation in thermodynamic materials using the IDEAS training project (ideas, evidence, and argument in science education). However, in the posttest, students were found to present no significantly higher skills, and they generally showed no rebuttal. A similar study has also been reported using the argument-driven inquiry module on the excretion system material [51]. Although that study has resulted in students' higher argumentation skills, their skills are still moderate. For students' argumentation skills are low-medium on thermodynamics material, with many students having false claims and descriptions at the collateral and support stages [52; 53]. Consequently, studies on college students' scientific argumentation skills have been extensively carried out, but only a low number of them adopted the dynamic electric material [54]. On the other hand, students are anticipated to be able to construct claims and present them through written or oral argumentative essays [55; 29].

The adoption of appropriate analogy can support the growth of students' scientific argumentation skills during electricity material learning [56]. Previous research also described the roles of analogy strategy as an effective learning strategy for abstract and complex materials, such as electricity, earth and space, earthquakes, and so forth [57; 58]. The analogy using familiar objects helps students understand a concept [59]. Another study explained that a combination of the analogy strategy and paradigm is effective in improving students' comprehension of the friction materials [60]. Generally, the instruction in the analogy learning strategy aids students in transforming the available or alternative concepts using the scientific conception, as well as presenting the appropriate explanation that can be understood easily [26; 61].

This analogy-based learning is supported by Dienes' learning theory which describes the importance of analogies and representations during the learning process to transform abstract concepts into more concrete ones, as well as to sort out the common elements in all provided concepts [36; 62]. In detail, Dienes's Theory describes that the learning of a concept can be comprehended in the analog progressive stage through Piaget's intellectual development, consisting of 1) free play, 2) games, 3) seeking commonality, 4) representation, 5) symbolization, and 6) formalization. Linearly, previous studies also reported students' progression in the representation, symbolization, and formulation stages [63; 64]. Dianes further described that representation helps college students sort out the standard features from concepts. The application of the analogy method is also linear and in parallel with the Bruner learning theory, in which Bruner divides learning into three stages active representation (action-based), iconic representation (image-based), and symbolic representation (language-based) [65; 66]. These three learning phases are commonly adopted as fundamental for mathematic representation studies. Similar to the available research, in iconic representation (image-based) and symbolic representation (language-based), the learning is initiated from visuals, such as figures, charts, and other abstract symbols, in the form of words, letters, sentences, and symbols [67].

THEORITICAL BACKGROUND

Scientific argumentation is a form of discourse that includes a reasoning process involving critical thinking skills [56; 68]. Toulmin identifies six key components of an argument, namely claim, data, warrant, backing, qualifier, and rebuttal [44; 46]. The claim represents the ability to present an argument based on the obtained information in answering a question. Data are facts used to support claims, while warrants are logical reasoning correlating the data to claims. Qualification is an attribute or description showing the validity of a claim, such as "always," "generally," "in condition," "mostly," "usually," " always," or " sometimes." Additionally, qualifiers can be defined as the ability to provide accurate answers based on the theory. The backing is additional support for warrants. In many cases, the warrant is implied, therefore, backing is present as a form of support to provide specific examples that justify the warrant. Specifically, backing represents the ability to provide support in answering all the proposed questions. Meanwhile, a rebuttal or disclaimer offers circumstances in which a person with a particular claim can revise or waive their claim. The ability to make rebuttals to challenge an opponent's view or point out the weaknesses of an opponent's argument demonstrates higher-order thinking skills [58; 69].

Several studies highlighted that scientific argumentation skills involve the comprehension of the discussed topics [70; 71]. Argumentation and reasoning skills play essential roles in completing assignments in the form of essays and argumentative texts [72; 73]. The study completed by [74; 75] also positioned argumentation skills as crucial for science students since science learning not only observes the natural law but also demands them to understand the laws. Essentially, scientific argumentation includes the establishment, refinement, and support of the claims based on scientific evidence [76; 77]. Academic ability also affects students' argumentation skills [67]. Therefore, students' argumentation abilities can be developed by facilitating students to construct knowledge meaningfully according to constructivism theory [78; 79].

Analogy is the process of identifying similarities between the new concept being discussed (a target) and the existing or familiar concept (called an analog) to assist students in understanding the new concept based on their prior knowledge [80; 81]. Meanwhile, representation is a sign or combination of signs, characters, objects, diagrams, or graphics in the form of actual physical products or mental processes which indicate and describe objects, physical properties, actions, relationships, or other more abstract objects [56]. Research exhibits that the accurate adoption of analogy-representation enhances students' learning motivation as they are facilitated to understand new concepts easily [82; 45]. Besides, the dynamic use of concrete and abstract representations of a factual object can improve freshman undergraduate students' understanding of the conceptually rich and complex phenomena compared to using only concrete objects [83]. However, analogy learning requires teachers to ensure that students memorize the learning content, not only the analogy, as it only serves as the media for students' conceptual, content, or process understanding [84; 85]. Research conducted by [86;70] reported that the optimum application of analogy necessitates accuracy between the analogy and the discussed concept. Meanwhile, analogy instruction assists students in transforming the available concepts into alternative ones using the scientific concept, helping them present the correct, logical, and easily understood conceptual explanation [87; 33]. In the dynamic electricity material, analogy is needed to visualize microscopic phenomena that exist as visible phenomena [87; 89]. In this study, we use the symbolization of actions between humans and transform them in the form of pictures or photos as the analogy for electrical circuits and their relationships. For example, shaking hands is analogous to a series circuit, while holding hands indicates a parallel circuit.

RESEARCH METHODS

In this study, 74 college students from Science Education of Universitas Negeri Surabaya, Indonesian, participated in two experiment classes. The data were in the form of students' argumentation skills garnered through pretest and posttest. For the test, we employed a scientific argumentation multiple-choice-reason test. This test was adapted from the Determining and Interpreting Resistive Electric Circuit Concept Test (DIRECT) [90], which added with reasoning section for each answer. Initially, DIRECT was constructed to evaluate students' understanding of electricity concepts, specifically in electrical circuits [42]. Before the data collection, the test underwent validity and empirical assessment to ensure its validity. The evaluation results showed 0.847 Cronbach's Alpha reliability, categorized as highly reliable. Additionally, we also gathered students' argumentation skills data through interviews. Referring to [29], students are instructed to participate in a simple interview for 10 minutes after they complete the pretest. During this interview, they were asked questions related to their process of formulating answers and their previous argumentation experience in the context of science learning or other fields. Further, we also obtained another data set from the questionnaire related to the implementation of analogy representation. This questionnaire sheet's validity had also been assessed. An example of an interview guideline is presented in figure 1.

In question item ... you provide answer as ... (based on students' answer).
Can you explain your reasoning or thinking process in formulating the answer?

Figure 1 Example of interview question

For the research methodology, we adopted a mixed method with a quasi-experimental approach and a one-group pretest-posttest design in table 3 [91]. In the initial stage, the lecturer provided the issues on differences between the parallel and series circuits, along with their electrical components in modified circuits. Then, students expressed their knowledge related to the concepts of parallel and series electrical circuits, electric current, power, and also resistance that are relevant to solving the problems. This process aims to train and broaden students' understanding of the concept of dynamic electric materials using argumentation. In the second stage, the lecturer briefly explained the concept of series and parallel electric circuits using an analogy-representational approach by symbolizing the electric circuits using human interactions directly and in the form of pictures or photos as subjects. In this process, students must analyze the presented analogy and determine the relevant analysis results to their initial claims. In the third stage, students were asked to make a mind map showing the information they had obtained, either as warrants or rebuttals. The fourth stage was a generalization, along with guidance from the lecturer, students transformed the concept from analogy-representation into a concrete form of physics concept. Furthermore, in the fifth stage (application), students were asked to apply that concept to their daily problems and communicate the analysis results in the form of written arguments. In the final stage of evaluation, the lecturer and students developed a conclusion. Then, the lecturer evaluated the students' skills through the scientific argumentation posttest.

Table 1

One Group Pretest Posttest Design

O_1	X	O_2
Pretest	Treatment	Posttest

STUDY RESULTS

The garnered data were analyzed qualitatively and quantitatively. Pretest and posttest data were analyzed using quantitative analysis, specifically the descriptive Statistics methods in the form of normality tests, paired t-tests, and N-gain tests to determine students' scientific argumentation skills and their progressions after learning using analogy-representation-based learning. Simultaneously, the results of the pretest and posttest as well as the student interviews, were also analyzed qualitatively using a data reduction. The results of data reduction are then classified according to the criteria for students' scientific argumentation skills shown in table 4 [28]. Further, these qualitative data were used as the secondary data supporting the quantitative data (pretest and posttest results), signifying the students' argumentation skills.

Table 2

Scoring Criteria for Students' Argumentation Skills

Level	Model	Criteria
1	Claim	Only provide claim (C)
2	Claim, Evidence	Provide claim and data (CE)
3	Claim, Evidence, and Warrant	Provide claim, data, and warrant (CEW)
4	Claim, Evidence, Warrant, and Backing	Give claim, data, warrant, and backing (CEWB)
5	Claim, Evidence, Warrant, Backing, Qualifier, and Rebuttal	Provide claim, data, warrant, backing, and rebuttal (CEWBQR)

In addition, the results of the questionnaire present students' opinions regarding the application of analogy learning strategy that were analyzed qualitatively. Each student's answer to the questionnaire item was given 1-5 scores. Then, the scores were calculated and interpreted using the criteria summarized in table 5 [37].

Table 3

Percentage Interval and Interpretation

Percentage Interval (%)	Interpretation
0.0 – 0.5	None of the indicators present
0.6 – 9.5	Almost none of the indicators present
9.6 – 39.5	Only a low number of indicators present

39.6 – 49.5	Almost half of the indicators appear
49.6 – 50. 5	Half of the indicators appear
50.6 – 59.5	More than half of the indicators appear
59.6 – 89.5	The majority of the indicators appear
89.6 - 99.5	Almost all of the indicators appear
99.6 – 100	All of the indicators appear

To identify the effect of the analogy-representation strategy on students' scientific argumentation abilities, the pretest and posttest results were compared. The results of the normality test analysis using the Kolmogorov-Smirnov test suggested 0.00 and 0.20 significance scores of the pretest and posttest, respectively, signifying a 0.05 difference. These obtained scores indicate that the post-test data are normally distributed.

In addition, the paired t-test and n-gain results suggested sig. (2-tailed) of $0.000 \leq 0.05$. As described by [80] if the $\alpha \leq 0.05$, then the H0 should be rejected, and the H1 should be accepted. As our analysis results showed α score of $0.000 \leq 0.05$, there is a significant difference between students' pretest and posttest scores after they learned using the analogy-representation learning in dynamic, eclectic material. Besides, we obtained a 0.318 N-gain score from the pretest and posttest results, which can be classified as moderate. Thus, in general, the obtained t-test and n-gain showed students' higher scientific argumentation skills after they attended the analogy-representation-based learning.

The ultimate goal of this discussion is to understand what has changed in the world of science as a result of this paper (in the author's opinion, of course); The direct task of the discussion is to justify the general conclusion, the main conclusion (or conclusion) of the paper. The results of this research show that analogy and representation-based learning has a significant impact on increasing students' scientific argumentation abilities on dynamic electrical material. This is supported by the results of the N-gain analysis showing a score of 0.318, which is included in the medium category. The paired t test produces a significance value of $0.000 \leq 0.05$ indicating a significant difference between the pretest and posttest results.

In detail, data related to students' scientific argumentation skills are shown through the distribution of argumentation levels before and after analogy and representation-based learning.

Level of Argumentation Skills

The participants' argumentation skills levels were observed through the pretest, posttest, and interview data. Figure 2 illustrates our participants' scientific argumentation criteria after they attended the analogy-based learning.

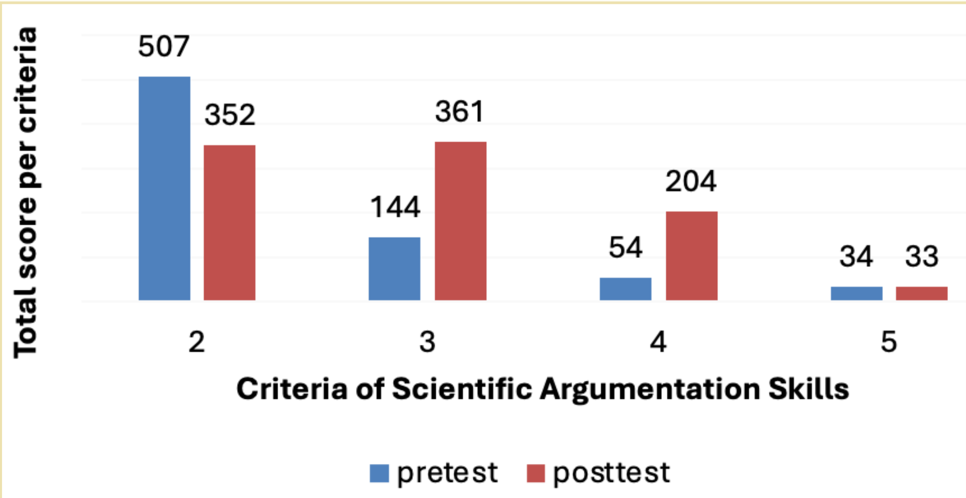

Figure 2 Participants' Argumentation Skills Levels

As presented in Figure 2, before attending the analogy-based learning, students have low argumentation skills, with the majority of them having level 2 argumentation skills, although some of them have level 3 and 4 argumentation skills. In the beginning, most of them only present claims and evidence. Following analogy-based learning, students have levels 3 and 4 of argumentation skills. Thus, analogy-based learning has successfully facilitated students to present warrant and backing in their argumentation. However, almost none of the students have levels 4 and 5 of argumentation skills. Even the number of participants having level 5 argumentation skills remains relatively the same. This finding suggests that students still face issues in constructing excellent scientific argumentation, completed with qualifiers and rebuttal. Essentially, analogy-based learning aims to enhance students' argumentation skills from level 2 to level 5.

Students' pretest and posttest scores also indicate an increase in their argumentation skills. Students' pretest scores showed that they primarily possessed level 0 argumentation abilities. However, after participating in the program, students' lowest argumentation skills were level 2. Besides, the pretest items that were initially in level 0 were transformed into level 2, at minimum (13 items). Therefore, the analogy-representation strategy has been confirmed to improve students' scientific argumentation abilities.

The examples of participants' pretest and posttest answers are shown in the following.

Examples of Answers in Level 5

Pretest

1 D. Circuit 1 and 2

Argument: A parallel circuit is where one currency is cut, and then the other circuit can still be turned on. That is, if 2 lamps are installed in parallel, then we can choose which lamp to be turned on. It can be seen that series 1 and 2 have 2 different paths.

Posttest

D. Circuit 1 and 2

Argument:

Series 1 and 2 are branched (data, evidence). Each lamp will get the same voltage (claim). The two circuits are not on the same cable path. This circuit follows the characteristics of a parallel circuit, where the resistance component is like an illustration or analogy of people holding hands; that is, the right hand meets the right hand, and the left-hand meets the left hand (Warrant). According to Kirchoff's Law 1, in a parallel circuit, the current that enters each resistance from the voltage source will be the same as the current that goes out to the voltage source (Backing). So that at parallel voltage, the voltage that each lamp or resistance has is the same as the source voltage

$$V = V_1 = V_2$$

While the current enters each lamp or resistance with a value according to the resistance (Qualifier)

$$I = I_1 + I_2$$

In the above question item, students are asked to provide an argumentation containing a claim, evidence, warrant, backing, and qualifier. During the pretest, the participant argued that "parallel circuit is when one current is cut, the other circuits remain undisturbed, therefore, when two lamps are in a parallel circuit, we can choose which lamp to turn on." That argument only consists of claims and evidence. In contrast, in the posttest, the same participant had provided the more complex argumentation, containing claim, evidence, warrant, backing, and qualifier. Further, during the pretest, students described that the question items were not difficult, but they encountered problems in building the argumentation. In contrast, during the posttest, they could work on the test and understand the concept in each question item easily. Therefore, students can establish argumentations, even at level 5. They also still reported problems in making rebuttals.

Examples of participant's answer Level 4

Pretest

1. E (Circuit 1, 2, and 4) Reason: Claim = Because in circuit 1, 2, and 4 is parallel circuit because it is not parallel in accordance with the concept of parallel and series electricity and in accordance with the nature of parallel, namely, each circuit has branches

Posttest

B. (Circuit II) Data → Circuit I = Series, Circuit II = Parallel, Circuit III = Series Claim → In circuit II the resistances are arranged in parallel Evidence → The answer is B, which is circuit II Warrant → In a parallel circuit, the resistance's right-hand holds the other resistance's right hand, and the left-hand holds the left hand. Backing → After being tested, the amount of V1 = V2 is 9 volts.

In question item no 1, students are asked to present arguments containing claim, evidence, warrant, backing, and qualifier (level 5). In the pretest, the participant described "because circuits 1, 2, and 4 are parallel as they have a branch in each of its circuits". This statement only contains a claim. Contrastingly, students' argument has a claim, evidence, warrant, and backing (level 4) during the posttest. The interview results also suggested that students still face problems in working on the items, particularly in determining the backing which correlates with the applicable formulas or laws. Thus, the participants have presented more excellent argumentation skills, yet their skills have not reached level 5.

Example of answer in Level 3

Pretest

3. (E) Where 2 and 3 are as bright, 1 and 4 are as bright but dimmer than 3. Kirchoff's law 1 (parallel circuit) states: That the amount of current leaving a branching point in a circuit is equal to the current going to that branching point so that the voltage across all parallel resistors is the same

Posttest

3. D Data: In that circuit, the appropriate ones are lamps 1 and 4, which carry the same current; 2 and 3 have the same current but less than 1 or 4. Warrant: In a parallel circuit, the two hands hold together Claim: The lights 1 and 4 will be brighter than lights 1 and 2 Backing: The series circuit on 1 and 4. The flowing current has the equation, namely $P = I^2.R$. The bigger the R, the bigger the P. Whereas in parallel, that is $P = V^2/R$ where the bigger the P, the smaller the R

In question item 3, students are asked to provide answers containing claims, evidence, warrant, backing, and qualifier. The pretest results showed that students' argumentation skills were still in level 2 (only claim and evidence), while in the posttest, they presented level 3 of argumentation skills (claim, evidence, and warrant). Simultaneously, the interview results also showed students' difficulties in establishing their argument.

Example of answer in Level 2

Pretest

3. C 1 is the brightest, 2 and 3 are the brightest, and 4 is the dimmest Argument: Lamp 1 has the brightest flame compared to the others because the brightness on number 1 is very close to the voltage source, while 2 and 3 have the same bright lights because the circuit is arranged in parallel, while lamp 4 is the dimmest because it is farthest from the voltage source

Posttest

3.) D 1 and 4 are bright, 2 and 3 are bright but dimmer than 4 Data and Evidence: There is a mixed electrical circuit Claim: The circuit consists of 4 identical lamps connected by a battery and an initially closed switch

In item number 3, students are also asked to present level 5 of argumentation skills (claim, evidence, warrant, backing, and qualifier). However, in this item, the participants' argumentation skills remain the same (only present the claim and evidence). The interview results indicate students' difficulties in solving the pretest and posttest, specifically in determining the warrant, backing, and qualifier. In most of the participants' answers, they restated the data or evidence from the question, and most of them did not understand the concept. The observation of their answers also showed their difficulties in making guarantors or logical and scientific reasons behind claims made based on data (warrants).

The findings from the posttest also showed that most students gave incorrect answers for questions number 11, 12, and 13. From their answers, we observed their issues in analyzing the correlation between current, resistance, and potential difference in an electric circuit. This is reinforced by 0.318 n-gain (medium category), signifying that some students are in the low category. Consequently, to resolve these issues, the use of more diverse, precise, and closer-to-life analogies is highly recommended as they aid students in relating one concept to another so they generate correct argumentation. Similarly, [14; 25] reported that familiar and appropriate analogies help students understand the learning content, concept, and process instead of only memorizing them. These results are in contrast with students' answers in question items number 1 and 2. Similarly, previous research has reported that familiar and appropriate analogies help students understand the learning content, concept, and process instead of only memorizing them. Additionally, the students' quantity and quality of arguments improve through time as they get more involved with argumentation [96]. These results are in contrast with students' answers in question items number 1 and 2. This is reinforced by the results of the research which states that the value of the argumentation category is low, so an innovative learning model is needed with analogies that are familiar and appropriate and can help students understand the content, concepts and learning process. rather than just memorizing it.

DISCUSSION

The analogy-representation strategy facilitates students in learning dynamic electricity material. The adopted analogy facilitates students to learn various electrical circuits, including the series, parallel, or the combination of series and parallel circuits. The analogy is through humans shaking hands and other symbolic visual representations. Even though previous studies have reported significant findings, the current trends demand learning to use analogies that is close to students' everyday life [59; 92]. Consequently, students are more familiar with the learning materials and construct their scientific understanding of the electricity and electric circuit materials as the analogy-representation aids them in connecting their new and prior information [93; 94]. Meanwhile, in providing the answers, students have to use argumentation to reinforce their skills [38; 68]. The argumentation skills are divided into five levels. In the first level, students only provide claims. In science, a claim can be in the form of conjectures, conclusions, explanations, or descriptive statements that answer the research problem. Students with excellent argumentation skills should provide the reasons for acceptance or rejection, along with the adequacy of evidence, while the students with level 1 argumentation skills only give the claims with no explanation [95]. Further, in level 2, students provide claim and evidence data. The evidence can be from the measuring and observation results that have been analyzed and interpreted [31]. At this level, students have not generated excellent scientific argumentation due to the absence of other argumentation components. Although they have presented the evidence, they have no warrant, which clarifies the correlation between the data and the claim [96].

What follows refers to the Results of the study in the pretest, most students were at argumentation level 2, while in the posttest, many increased to levels 3 and 4. This shows an increase in students' ability to formulate claims, evidence, warrants, and backing in explaining arguments related to the concept of dynamic electricity. This increase is relevant to the results of the study [20] which states that the integration of learning strategies involving analogies can help students understand abstract concepts more deeply and develop stronger scientific arguments. This finding is also in line with [11] that analogy-representation-based learning not only improves conceptual understanding, but also students' ability to connect theory with concrete applications, namely scientific argumentation.

Despite the improvement in scientific argumentation skills, most students are still at argumentation levels 3 and 4, with only a few reaching argumentation level 5. This finding is not entirely in line with the theoretical idea put forward by Toulmin who explains the importance of rebuttal and qualifier as indicators of high-level scientific argumentation. The low level of argumentation indicates that students still face obstacles in constructing arguments that include rebuttals to identify weaknesses in their arguments or those of others.

The questionnaire results showed that 90% of students stated that analogy-representation-based learning helped students understand abstract and complex dynamic electricity concepts faster with appropriate arguments according to the concept. 100% of students considered the analogy used to be relevant to their daily lives, so that students could write their arguments appropriately according to the dynamic electricity concept. This supports the results of research conducted [5], which found that analogies relevant to daily life have great potential to make it easier for students to understand complex physics concepts.

This study confirms that the analogy-representation strategy is effective in bridging the gap between theory and practical application, thus providing a new direction in improving the quality of science learning at the higher education level. The impact of this study for the world of science in general is to emphasize the importance of using appropriate analogies and connecting them to everyday life in learning to overcome difficulties in understanding abstract concepts, especially in complex subjects such as dynamic electricity.

The analysis results on students' answers suggested that students can analyze series and parallel circuits (the provided circuit examples shown are different from the general examples found in the textbook as they have been modified), as well as their relationship to the lights on. In this case, for the analogy-representation, human shaking hands is adopted as the analogy. This analogy has proven to be effective in facilitating students in understanding the concept of series and parallel circuits due to its close familiarity with students' lives. The previous studies [97; 98] also discovered that familiar goods or activities serve as the more effective analogy for students' learning activities. Therefore, analogy representation is efficient for aiding students' comprehension of the dynamic electricity materials and argumentation skills [61; 99].

Effects of analogy-representation toward dynamic electric learning

Students' perception of the usage of analogy-representation-based learning was observed through the analysis of their responses to a questionnaire. The questionnaire containing nine items related to the application of analogy-representation learning was distributed to 74 respondents. The results suggested that 90% of students stated that analogy-representation-based learning helps them understand abstract and complex dynamic electricity concepts more quickly. Besides, the learning can help transform dynamic electricity concepts into concrete forms (visualization). Furthermore, 100% of students stated that the analogies used in learning are familiar to their everyday activities.

In addition, although we also uncovered several learning obstacles, the majority of students can understand dynamic electricity materials more efficiently. Following the learning, students' greater understanding is exhibited through their explanation completed with the data obtained from the questions. [72; 27] reported students' excellent argumentative scientific essays using the data presented in the question items. The previous study has reported that students have excellent argumentative scientific essays using the data presented in the question items [72]. Evidence indicates that reasoning ability constitutes a fundamental component in the production of high-quality assignments, especially those in the form of essays and argumentative texts. Meanwhile, other studies [86; 72] suggested the importance of college students' argumentation or analogy skills in completing the question items. Scientific argumentation and students' understanding of concepts are closely correlated. One element that contributes to students' lack of reasoning skills is a lack of conceptual knowledge. Further, the argumentation style shows a person's level of conceptual understanding and reasoning. [79; 100] described that students' effective argumentation skills progression requires the ability to interpret a concept. The previous research has described that students' effective argumentation skills progression requires the ability to interpret a concept [100]. This ability is needed in creating scientific argumentation, as the formulation of claims and the submission of reasons. Consequently, an increasing conceptual mastery will be achieved when students involve in constructing the argumentation.

The students' scientific argumentation skills in solving dynamic electricity problems are also supported by the results of interviews. Similar to previous studies, scientific argumentation skills are observed through the students' capacity to construct Cldonov aims and present them in written and spoken argumentative essays [40; 76]. Students possessing argumentation skills at levels 2 and 3 often struggle to comprehend the data and claims they present in questions, leading to difficulty expressing their ideas coherently in essay format due to their limited grasp of the underlying concepts. This is probably caused by students' incorrect conceptual understanding and analogy. Also, [86; 43] described that the appropriate adoption of analogy would optimize students' conceptual mastery, so their academic skills are crucial for their scientific argumentation skills. Through analogy, students can visualize the abstract concept as they can compare their similarities [50; 82]. The addition of a suitable analogy will enhance the learning process [86; 101]. Thus, learning using metaphors can facilitate students to solve problems and state the concepts they have learned through scientific arguments, both written essay and verbal, precisely because they understand the accuracy of the learning material.

In this context, we started the learning by presenting the analogy for series, parallel, and mixed electric circuits. In the series circuit, we used the analogy of one hand holding other people's hands, and leaving the other hand to do any other activities. For the parallel circuits, we adopted the analogy of two hands holding the hands of other people [102]. Through these analogies, students analyze the series-parallel electricity circuit. As described in the previous studies, with the familiar analogy, students can understand and memorize the learning content optimally [84; 86].

Our analysis results suggested that the adoption of daily activities as an analogy in learning promotes students' conceptual understanding. Previous studies [66; 59] asserted that a familiar analogy can visualize a concept optimally. The optimum effects of analogies on students' argumentation skills are observed through their pretest and posttest results, along with their excellent argumentation structure [103; 104]. Great structure helps students state their arguments orally. Further, our findings also suggested that students' higher argumentation skills are linear with their conceptual understanding of electricity material. In the end, with excellent argumentation skills, students can be directed to enhance their bravery to communicate in public. These skills are crucial for their life in society as they realize critical and realistic perspectives on their life problems which generate better life decisions

The apparent result of this study indicates that the use of analogy-representation enhances students' scientific argumentation skills, especially in writing. The use of these analogies and representations in an instructional context aids students in acquiring and developing the skills for producing and evaluating arguments [105; 106]. Additionally, argumentation skills are crucial both in the present and the future as they play a vital role in fostering cognitive and metacognitive development, enhancing communication abilities, promoting critical thinking, facilitating scientific literacy, and advancing students' reasoning capabilities [39]. Globally, argumentation skills also carry important roles in science education, particularly in generating eminent future generations [68]. Given the importance of this skills, it is essential to take initiatives to enhance students' scientific argumentation skills [107], such as through incorporating analogy-representation methods. The use of analogy-representations related to everyday life facilitates students to understand the material and improve their scientific argumentation skills. However, several influencing aspects of argumentation skills have not been discussed in this studies. Thus, future researchers are suggested to investigate other influencing factors related to argumentation, such as personality characteristics or sociocultural differences in assessing arguments and the means to express disagreement. This research contributes to the improvement of students' argumentation abilities, while the variables and the results of this study can also be used as future references in determining more effective treatments to improve students' scientific argumentation skills.

CONCLUSION

There are five categories of scientific argumentation skills in solving dynamic electricity problems. These levels are distinguished by students' ability to present data or evidence, claims, warrants, backings, and qualifiers. Our analysis results showed that analogy-based learning significantly improves students' scientific arguments with an n-gain of 0.381 (medium category). In addition, we found that a small number of students can solve questions with levels 2 and 3 of argumentation skills. On the contrary, following the implementation of analogy-based learning, students' scientific argumentation skills improved, becoming more organized and coherent, aligning with the concepts and data presented in the questions. In the end, we concluded that the adoption of appropriate analogies is crucial in analogy-based learning to facilitate students to express their arguments easily through essays and oral presentations. Analogy learning is designed to improve students' scientific argumentation skills, especially dynamic electricity material.

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The author's declared no conficts of interest