IJIS Edu : Indonesian J. Integr. Sci. Education, 7 (1) 2025

Volume 7 Issue 1 , Januari 2025
P-ISSN: **2655-2388**, E-ISSN: **2655-2450**

Prospective Primary School Teachers' Understanding of Model Representation: The Case of Static Electricity

Rifat Shafwatul Anam[1], Rendi Restiana Sukardi[2], Monika Handayani[1], Roseleena Anantanukulwong[3], Titiyaka Jajuri[4]

[1]*Universitas Tebuka, Jl. Cabe Raya Pondok Cabe Pamulang, Tangerang Selatan Banten Indonesia 15437*
[2]*Universitas Pendidikan Indonesia, Jl. Pendidikan No.15 Bandung Regency West Java Indonesia 40625*
[3]*Yala Rajabhat University, 133 Thetsaban 3 Road, Tambol Sateng, Amphoe Mueang, Yala Province 95000 Thailand*
[4]*Kolej Matrikulasi Perak, 31600 Gopeng Perak Darul Ridzuan Malaysia*
Corresponding E-mail: rendisukardi@upi.edu

Abstract: This study aimed to assess the comprehension levels of prospective primary school teachers regarding verbal and visual representation models of static electricity. A survey was conducted involving 110 prospective teachers from West Java Province, selected through purposive sampling. Participants were categorized based on their secondary school study programs and gender. The study utilized a five-tier test as the instrument for data collection, with responses analyzed using descriptive statistics. Verbal and visual responses were categorized into several levels. Analysis revealed that the majority of both verbal and visual responses fell into the lack of knowledge, misconception, unidentified categories. These findings highlight the inadequate understanding of static electricity concepts among prospective primary school teachers, which may contribute to students' difficulties. Differences in educational background and gender did not significantly influence the comprehension levels in either verbal or visual representations of static electricity concepts. This provides insight into the fact that the topic of static electricity, though often regarded as straightforward and revisited at various educational stages from primary to secondary school, remains a source of widespread misunderstanding and error. The study underscores the critical need for targeted interventions in teacher education programs to enhance understanding and effective teaching of scientific concepts like static electricity at the primary school level.

Keywords: static electricity, five-tier test, visual representation, verbal representation, gender

How to cite this article :

Anam, R., Sukardi, R., Handayani, M., Anantanukulwong, R., & Jajuri, T. (2025). Primary School Teachers' Understanding of Model Representation: The Case of Static Electricity. *IJIS Edu : Indonesian Journal of Integrated Science Education, 7*(1). doi:http://dx.doi.org/10.29300/ijisedu.v7i1.5009

1. Introduction

A deep understanding of content knowledge on the subject of static electricity is crucial for teachers as it directly affects how they teach this concept to their students (Campos et al., 2023; Ivanjek et al., 2021; Onder-Celikkanli & Tan, 2022). When teachers possess a strong grasp of static electricity, they can explain these concepts more clearly and thoroughly, enabling students to understand the material better. Good content knowledge allows teachers to address various student questions, provide detailed explanations, and use a variety of effective teaching methods. This also helps in identifying and correcting students' misconceptions about static electricity. Therefore, mastery of content by teachers not only enhances the quality of teaching but also ensures that students gain a deep and comprehensive understanding of static electricity concepts, which are fundamental in science education.

Model representation is crucial for prospective primary school teachers. The ability to use models in teaching is believed to enhance the prospective teachers' ability to convey abstract concepts to students (Barth-Cohen et al., 2024; Fricke & Reinisch, 2023; Pierson et al., 2023). Model representation helps teachers simplify and explain concepts that may be difficult to understand if conveyed only verbally. By using models, prospective teachers can make complex concepts more concrete and understandable for students, making learning more effective and engaging.

Many concepts in science, such as atoms, molecules, magnetic fields, and electromagnetic waves, are abstract and cannot be directly observed. In this case, scientific representations such as models, diagrams, graphs, and simulations become highly useful tools. Scientific representations allow students to visualise and understand complex concepts more clearly. By using these representations, students can connect theory with concrete visualisations, thereby strengthening their understanding of abstract science concepts. This makes science learning more effective and engaging for students (Pierson et al., 2023).

Research shows that electricity is one of the difficult concepts to visualise for science or physics teachers at various educational levels (Lestari et al., 2018; Saputro et al., 2018). Due to its abstract nature, the concept of electricity can be difficult for students to grasp, including primary school students who have lower abstract reasoning abilities. Children at this level often struggle to understand phenomena that they cannot see or experience directly, making them more prone to misconceptions. Additionally, other research reveals that students' understanding of electrical concepts often involves misconceptions (Akan, 2012). These misconceptions can hinder their future learning because a basic understanding of electricity is crucial for comprehending more complex scientific knowledge later on.

Common misconceptions include misunderstandings about how electric current flows, the nature of electric charge, and the relationship between electricity and magnetism (Koca, 2022; Moodley & Gaigher, 2019; Sengupta & Wilensky, 2009). Therefore, it is essential for teachers to use effective teaching methods and clear model representations to help students overcome these difficulties. With the right teaching strategies, teachers can help students develop a more accurate and deep understanding of electrical concepts, enabling them to avoid misconceptions and be better prepared to learn more complex science material in the future.

Students' understanding of static electricity concepts has not been fully explored, especially when asked to draw or create visual representations (Koca, 2022). Often, the drawings produced by students only include macroscopic aspects, such as a balloon sticking to a wall after being rubbed with a cloth or hair standing on end when combed. Such representations indicate that students' understanding is still limited to phenomena they can see and experience directly. They rarely, if ever, depict more fundamental sub-microscopic aspects, such as the distribution of charges on the surface of objects or the interactions between electric charges at the particle level.

A deep understanding of static electricity requires the ability to link visible phenomena with processes occurring at the particle level (Anam et al., 2023; Kapici, 2023). For example, understanding how electrons move from one object to another and how this charge distribution creates an electric field that causes objects to attract or repel each other. Without this understanding, students may be able to observe and describe static electricity phenomena but not truly comprehend the underlying principles. Therefore, it is important for teachers not only to teach static electricity concepts macroscopically but also to help students understand and depict sub-microscopic aspects. This approach can be implemented through the use of models, diagrams, and simulations that illustrate interactions at the particle level, allowing students to develop a more holistic and profound understanding of static electricity.

Although much research has been conducted to measure concept comprehension among prospective primary school teachers, no study has specifically measured the model representation abilities of prospective primary school teachers related to static electricity. This highlights a gap in research that needs to be filled to improve the quality of science education at the primary level. The importance of model representation in science teaching cannot be overlooked, especially considering that concepts like static electricity are often abstract and cannot be directly observed by students. By understanding and being able to use effective model representations, prospective primary school teachers can present this material more clearly and engagingly, helping students to better understand the concepts (Anam et al., 2023).

Good model representation helps students link observable phenomena with underlying scientific processes, which is a crucial skill in scientific understanding (Kapici, 2023). The lack of research focusing on this aspect means we may be missing opportunities to identify and address deficiencies in the training of prospective primary school teachers, particularly regarding the use of models to teach static electricity concepts. Thus, research measuring the model representation abilities of prospective primary school teachers will not only fill the gap in the literature but also provide valuable insights for teacher training programmes. This, in turn, will positively impact the quality of science teaching at the primary level, enabling students to have a deeper and more comprehensive understanding of important scientific concepts (Barth-Cohen, Dobie, Gutiérrez, Carlsruh, & Greenberg, 2024; Chi, Wang, & Qian, 2024;

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Plummer & Cho, 2024; Quinlan, 2024; Zhong, Rogers, Nicholas, Danish, & Hmelo-Silver, 2024).

This research is vital because it not only provides information about prospective teachers' model representation on static electricity but also offers recommendations for future steps. For instance, this research can suggest suitable teaching methods not only for primary school students but also for prospective teachers themselves, making learning more effective and efficient.

The novelty of this research lies in the use of a measurement tool called the five-tier test. This tool not only explores verbal responses from prospective primary school teachers but also their visual responses and their level of confidence in responding. This approach allows for the collection of more accurate and comprehensive data regarding the understanding and abilities of prospective teachers in representing concept models, providing deep insights that can enhance the effectiveness of future training and teaching.

This research is expected to make a significant contribution to improving the quality of science education at the primary level. Its results can also be used to design better training programmes for prospective primary school teachers, enhancing their readiness and competence in teaching science concepts to students. Thus, the implementation of findings from this research has the potential to bring substantial improvements to teaching methods and students' understanding of natural science at the primary education level.

Various efforts are being made to overcome the difficulty of teaching electrical concepts through the implementation of various science activities, but efforts to explore the conceptions of prospective teachers are still very limited. However, it is important to know and analyse prospective teachers' conceptions to project whether students' difficulties in understanding electrical concepts are influenced by weak conceptions of teachers or prospective teachers. Moreover, many electrical conceptions of prospective teachers or teachers are revealed only from the perspective of knowledge tests without involving the teachers' visual representations of electrical concepts.

In this research, a five-tier test is used, combining the cognitive dimensions of prospective primary school science teachers and their visual representations of electrical conceptions (Suparman et al., 2024; Taban & Kiray, 2022; Türkoguz, 2020). The selection of the five-tier test is based on several important reasons. First, this test will examine electrical conceptions macroscopically, relating to physical symptoms or phenomena associated with electricity. Second, this test seeks to explore teachers' scientific reasons for viewing electrical phenomena from a sub-microscopic perspective. This is crucial because it reveals the electrical conceptions of prospective teachers in abstract dimensions. Lastly, this test facilitates teachers in expressing their visual representations of abstract and invisible phenomena. In the context of this last objective, very limited research explores the visual representation dimensions of prospective primary school science teachers. Therefore, based on the facts about electrical conceptions and the limited research on integrating visual representations in investigating electrical conceptions, through this research, we aim to analyse the electrical conceptions of prospective primary school science teachers using the five-tier test.

Effective teaching of static electricity relies on teachers' strong content knowledge and ability to address misconceptions. While existing research highlights the role of models in simplifying abstract concepts and bridging macroscopic phenomena with particle-level processes, limited studies focus on how prospective primary school teachers utilise model representations for static electricity. Misconceptions, such as misunderstandings of charge distribution and current flow, remain prevalent due to the abstract nature of electricity. Scientific representations, including diagrams and simulations, are essential for overcoming these challenges, yet most research emphasises verbal explanations over visual representation skills. This study addresses these gaps by using the five-tier test to assess prospective teachers' verbal and visual responses, providing a comprehensive analysis of their conceptual understanding. The findings aim to enhance teacher training programmes by improving prospective teachers' ability to represent abstract concepts effectively, ultimately strengthening primary science education.

This research seeks to achieve distinct objectives compared to similar studies by focusing on two measurement aspects—verbal and visual responses—through the five-tier test. Unlike conventional approaches that predominantly evaluate verbal explanations, this study integrates visual representations to uncover deeper insights into how prospective primary school teachers conceptualise and communicate static electricity. The research aims to provide a dual-layered understanding: (1) identifying how teachers express their comprehension of static electricity verbally and visually, and (2) analysing the interplay between these modes of representation to highlight gaps in their understanding. This approach not only bridges macroscopic and sub-microscopic perspectives but also illuminates specific challenges teachers face when conveying abstract concepts. Ultimately, the findings are expected to inform teacher training programmes by addressing deficiencies in conceptual and representational skills, thereby equipping future educators to teach abstract scientific concepts more effectively at the primary education level. This holistic understanding could also serve as a foundation for designing targeted instructional strategies and assessment tools for science education.

2. Method

The study employs a survey design to explore the electrical conceptions of prospective primary school science teachers using a five-tier test. The research focuses on the concepts of static electricity, conductors and insulators, and electrical circuits, in line with the primary school curriculum in Indonesia. The sample consists of 110 prospective primary school teachers from various higher education institutions in West Java, selected using purposive sampling techniques. The main instrument is the five-tier test, which combines verbal and visual questions to measure students' understanding. Data is analysed by categorising students' conceptions into macroscopic and sub-microscopic levels, and assessing their visual representations across six different levels. The results are expected to provide deep insights into the

Online ISSN 2655-2450 | Print ISSN 2655-2388

understanding and model representation abilities of prospective primary school teachers regarding electrical concepts.

Research Design

In this study, we use a survey design to obtain data on the electrical conceptions of prospective primary school science teachers. The rationale for using a survey research design is to collect abundant data (Schmidt, 1997). The process involves several stages. First, we define the boundaries or scope of the survey. In this phase, we identify electrical concepts as the focus of the survey. Electrical conceptions are divided into three sections: static electricity, conductors and insulators, and electrical circuits. These concepts are chosen based on the primary school curriculum, where these topics are taught to primary school students in Indonesia. Second, after establishing the scope, we develop tests to assess the conceptions of primary school science teachers regarding electrical concepts. Third, we set procedures for the prospective science teachers to follow when participating in the survey. In the context of this research, the procedures relate to the protocols that prospective primary school science teachers follow when completing the tests and drawing.

The five-tier test is particularly well-suited for measuring the conceptions of primary school teachers regarding static electricity due to its comprehensive and multi-dimensional approach. Unlike traditional assessment tools, this test examines not only the correctness of responses but also the depth of understanding, confidence levels, reasoning skills, and the ability to represent abstract concepts visually. These attributes are crucial when assessing a complex and abstract subject like static electricity, where misconceptions are common and often deeply rooted.

The five-tier test goes beyond surface-level understanding by requiring teachers to provide explanations for their answers. This aspect allows researchers to distinguish between accurate knowledge based on scientific reasoning and correct answers derived from guesswork or rote memorisation (Assimi, Janati Idrissi, Zerhane, & Boubih, 2024; Irmak, İnaltun, Ercan-Dursun, Yaniş-Kelleci, & Yürük, 2023; Taban & Kiray, 2022; Yang et al., 2024). For example, a teacher might correctly identify that a charged balloon sticks to a wall but provide an incorrect explanation, revealing a partial or flawed understanding.

The confidence tier enables the identification of areas where teachers may have doubts about their knowledge. Confidence ratings are particularly valuable in understanding the stability of teachers' conceptions. A teacher with low confidence, even when their answers are correct, may require further training to solidify their understanding.

The inclusion of visual representations makes the five-tier test especially suitable for evaluating static electricity concepts. This dimension allows teachers to demonstrate their ability to conceptualise and communicate abstract ideas, such as charge distribution or the interactions between particles, which are fundamental to understanding static electricity. Visual representation is critical in teaching, as it helps bridge the gap between abstract phenomena and students' concrete experiences.

Finally, by categorising responses into *scientific conceptions*, *misconceptions*, and *no conceptions*, the test provides nuanced insights into teachers' understanding. This categorisation aids in identifying specific areas of misconception, such as misunderstandings about electric charge behaviour or the relationship between static electricity and electric fields. These insights are essential for designing targeted professional development programmes to address gaps in knowledge.

Sample and Participants

The sample in this study comprises prospective primary school science teachers from higher education institutions in West Java, Indonesia. The selection of both public and private institutions is based on purposive sampling techniques due to the researchers' ease of access (Barratt & Lenton, 2015). From the defined sample, we involve second-year prospective primary school science teachers. Generally, the average age of the participants ranges from 18 to 19 years old. The total number of participants contributing to this study is approximately 110 individuals.

Instruments

The research instrument used in this study is the five-tier test. In detail, the first and third questions are content tiers and consist of several choices—four answer options where the researchers provide three choices from one to three, and students can propose an alternative as the fourth option. The first question asks respondents to predict what phenomenon will occur in an experiment, aiming to investigate their macroscopic representation level. The third question asks students to explain the reasoning behind the phenomenon that occurs in the experiment, aiming to examine their sub-microscopic representation level. The second and fourth questions are confidence tiers that measure students' certainty levels in choosing content tiers. At this level, we provide two options: certain and uncertain. Finally, the fifth question is the drawing tier, which asks students to provide visual representations based on scientific concepts. An example of the instrument is presented in Figure 1 below.

The data collected from primary school teachers will be processed using descriptive statistics, resulting in a percentage breakdown of their understanding of static electricity concepts. This quantitative data will be further enriched with qualitative data obtained through follow-up interview questions, aimed at clarifying responses that lack detail or appear ambiguous. For instance, teachers' understanding will be categorized into distinct groups such as *scientific conception*, *misconception*, or *no conception*. This combined approach ensures a comprehensive analysis, highlighting not only the prevalence of accurate and inaccurate conceptions but also uncovering the underlying reasons for such variations in understanding.

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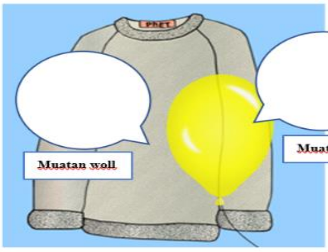
Pertanyaan:

Shabina melakukan percobaan sederhana mengenai konsep "kelistrikan". Dia menggosokkan balon secara searah pada kain wol (*sweater*). Setelah digosok-gosokan balon tersebut didekatkan ke arah wol, seperti terlihat pada gambar di bawah ini!

Question:
Shabina conducted a simple experiment on the concept of "electricity." She rubbed a balloon in one direction on a wool cloth (sweater). After rubbing, the balloon was brought close to the wool, as shown in the image below.

	
Sebelum digosokan antara balon dan wol *Before rubbing between the balloon and the wool*	Setelah digosokan antara balon dan wol *After rubbing between the balloon and the wool*

Pertanyaan level makroskopik:
Apakah yang akan terjadi pada balon yang didekatkan pada wol tersebut dan mengapa hal tersebut terjadi?

Macroscopic level question:
What will happen to the balloon when it is brought close to the wool, and why does this occur?

a. Balon akan mendekat pada wol tersebut karena adanya perbedaan muatan antara keduanya.
The balloon will move towards the wool due to the difference in charge between them.
b. Balon akan mendekat pada wol tersebut karena adanya penambahan muatan elektron pada keduanya
The balloon will move towards the wool due to the addition of electrons to both.
c. Balon akan mendekat pada wol tersebut karena adanya pengurangan dan penambahan elektron pada balon
The balloon will move towards the wool due to the reduction and addition of electrons on the balloon.
d. …………………………………………………………………………………….

Tingkat keyakinan

Apakah Anda yakin dengan jawaban tersebut?

Confidence level
Are you confident with your answer?

Alasan:

Mengapa hal itu dapat terjadi pada peristiwa tersebut?

Reason:

Why does this phenomenon occur?

a. Elektron dan proton dari kain wol berpindah ke balon sehingga balon terjadi penambahan elektron dan proton dibandingkan dengan wol
Electrons and protons from the wool cloth move to the balloon, resulting in an increase in electrons and protons on the balloon compared to the wool.
b. Beberapa elektron dari wol akan berpindah yang mengakibatkan elektron dan proton pada balon semakin banyak.
Some electrons from the wool will transfer, resulting in more electrons and protons on the balloon.
c. Elektron dari wol berpindah ke balon sehingga mengakibatkan balon bermuatan lebih negatif dibandingkan wol.
Electrons from the wool move to the balloon, causing the balloon to become more negatively charged compared to the wool.
d. ……

Tingkat keyakinan

Apakah Anda yakin dengan jawaban tersebut?

Confidence level

Are you confident with your answer?

Figure 1. The Example of Instrument

After the data collection process through the test, in the following period, we sought to confirm how the prospective science teachers perceived the visual representations they created. The instrument used in this interview process was an interview sheet containing several questions regarding the primary science teacher candidates' views on visual representation and the difficulties they faced when creating visual representations. Not all participants were involved in the interview process. Only 10% of the total participants were included in this data collection process, and the selection was done through purposive sampling (Robinson, 2014). The reason for this is that the interviewed participants would provide qualitative data that show nuances different from others. This is based on the visual representations they had created.

Data Sources and Analysis

In this study, we obtained two different types of data: the electrical conceptions from a macroscopic and sub-microscopic perspective, and the electrical conceptions in the form of visual representations. These two types of data will be analysed differently. First, we analysed the conceptions of the prospective teachers at the macroscopic and sub-microscopic levels. Then, we coded these conceptions into five levels, as

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shown in Table 1: Scientific Conception (SC), Almost Scientific Conception (ASC), Misconception (MSC), Have No Conception (HNC). Here, we analysed the responses of the prospective teachers by presenting a frequency analysis. Each student response that represents their understanding at these two levels was counted. Second, we coded the drawing tier results to categorise six levels of students' visual representations: Scientific Drawing (SD), Partial Drawing (PD), Misconception Drawing (MD), Undefined Drawing (UD), Non-Microscopic Drawing (NMD), and No Drawing (ND), as shown in Table 2. We used a rubric to code the students' visual representations, and this was based on the explanation of each drawing category. The rubric was assessed by two experts with expertise in physics. We also conducted interviews to obtain detailed information regarding what they depicted.

3. Result and Discussion

This section presents the findings from the assessment of verbal conceptions held by prospective primary school teachers concerning the concept of static electricity. The study aimed to evaluate the depth and accuracy of their understanding and their ability to articulate these concepts effectively. The results indicate a significant gap in the scientific understanding of static electricity among the teacher candidates. Both male and female participants struggled to demonstrate clear and accurate comprehension of the topic. Despite their confidence in discussing the concept, their verbal explanations revealed fundamental misconceptions and a lack of thorough knowledge.

The analysis further categorizes the candidates' responses, highlighting the prevalence of misconceptions and the absence of scientifically accurate explanations. This underscores a critical area for improvement in teacher education programs, emphasizing the need for enhanced instructional strategies to foster a deeper and more precise understanding of fundamental physics concepts. Addressing these gaps will better prepare future educators to teach static electricity with confidence and accuracy, ensuring they can effectively convey these important scientific principles to their students. This prologue sets the stage for a detailed exploration of the specific findings and their implications for teacher education.

Verbal Conception of Prospective Primary School Teachers on the Concept of Static Electricity

Based on Figure 2, it is proven that neither male nor female prospective teachers possess a scientific conception of static electricity. This observation reveals a significant gap in their understanding of fundamental physics concepts. The inability to grasp these basic principles suggests that their foundational knowledge in physics is weak, which could severely impact their effectiveness as future educators. Remarkably, none of the prospective teachers fall into the Lack of Confidence (LC) category, indicating a universal sense of confidence among them. However, this confidence is misplaced, as it is not backed by adequate knowledge. The root issue is not a lack of confidence but a deficiency in their understanding of static electricity, which can lead to ineffective teaching methods and potentially propagate misunderstandings among their future students.

The graph provides a detailed breakdown of the categories of prospective teachers based on gender and their high school academic background. The blue bars represent prospective female teachers who pursued science during their high school education, while the red bars depict prospective male teachers with the same academic background. The green bars indicate prospective female teachers who did not study science in high school, and the purple bars represent prospective male teachers from non-science streams. This categorisation allows for a comprehensive comparison of conceptual understanding across different gender and academic backgrounds.

The data shows that the Lack of Knowledge (LK) category is almost equally populated by female candidates with a science education background, male candidates with a science background, and female candidates from non-science backgrounds. This uniformity implies that the problem is systemic, affecting prospective teachers irrespective of their educational backgrounds. It suggests that current educational approaches fail to sufficiently address the learning needs of students from diverse academic histories. In the Misconception (MSC) category, male candidates with a science education background are the most prevalent. This dominance is particularly concerning as it indicates that even those who have specialized in science during their education are susceptible to significant misunderstandings. This finding challenges the assumption that a science background necessarily equates to a better understanding of scientific concepts, highlighting a critical area for curriculum improvement (Andersen & Munksby, 2018; Gumilar, Hadianto, Amalia, & Ismail, 2022; Unsworth & Herrington, 2023; Zheng, Cordner, & Spears, 2022).

Despite the issues identified, it is important to note that every prospective teacher has some conception of static electricity. This indicates that the education they have received over the past 12 years has been somewhat effective in imparting basic knowledge. While none have achieved a scientific conception, the presence of some level of understanding suggests that there is a foundation upon which to build more accurate and comprehensive knowledge. The findings imply that while the educational system has succeeded in instilling a basic awareness of static electricity, it has fallen short in ensuring a deep, scientific understanding. This underscores the need for a re-evaluation of teaching methodologies in teacher education programs. Educators must be equipped with strategies that not only boost confidence but also ensure a thorough comprehension of scientific concepts to avoid the perpetuation of misconceptions.

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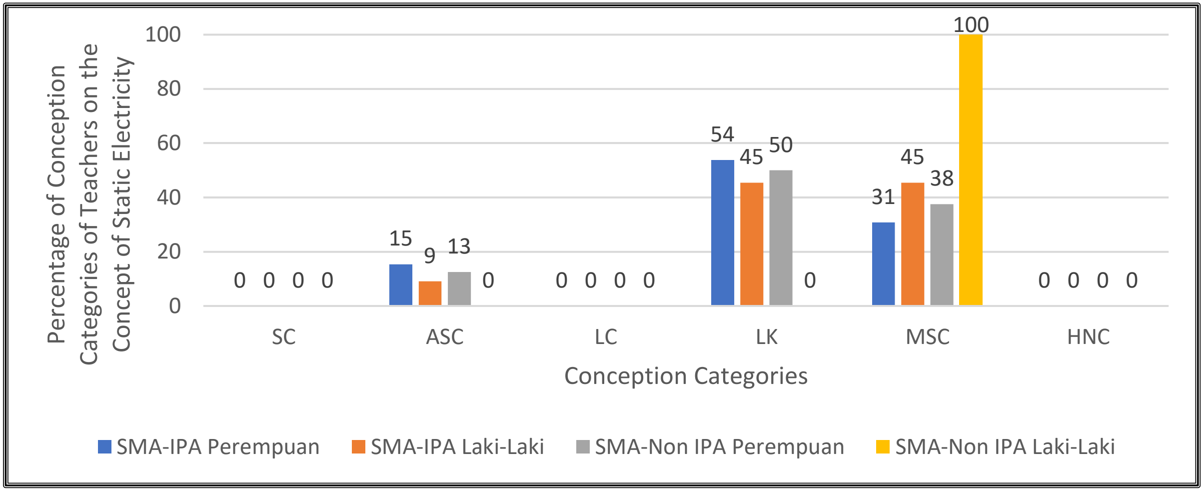

Figure 2. Verbal Conception on the Concept of Static Electricity

To address these deficiencies, it is recommended that teacher training programs incorporate more experiential learning and critical thinking exercises. These methods can help prospective teachers develop a deeper understanding of static electricity and other fundamental concepts. Additionally, continuous professional development should focus on identifying and correcting misconceptions, enabling teachers to provide clear and accurate explanations. By improving teaching strategies and focusing on conceptual mastery, the education system can better prepare future teachers, ultimately enhancing the quality of science education for their students (Sopandi, Kadarohman, Rosbiono, Latip, & Sukardi, 2018; Sopandi & Sukardi, 2020; Sukardi & Agustrianti, 2017).

The low understanding of static electricity concepts among prospective primary school teachers, particularly in writing responses and representing them both visually and verbally using a five-tier test, can be attributed to several factors. Firstly, static electricity involves invisible processes at the atomic and molecular levels, making it difficult for students to visualize and understand. This abstract nature poses challenges in both conceptual understanding and representation (Onder-Celikkanli & Tan, 2022). Secondly, teacher education programs may not provide sufficient focus on deep understanding and effective teaching strategies for complex scientific concepts. Without strong content knowledge, prospective teachers struggle to explain and represent these concepts accurately (Fricke & Reinisch, 2023). Thirdly, prospective teachers often enter training programs with pre-existing misconceptions about static electricity, such as misunderstandings about charge transfer and the nature of electric forces. These misconceptions can persist and affect their ability to accurately represent the concepts (Akan, 2012; Koca, 2022). Additionally, limited opportunities for hands-on, inquiry-based learning experiences in teacher education can hinder the development of a robust understanding of scientific concepts. Practical experiences are crucial for visualising and internalising abstract ideas (Moodley & Gaigher, 2019). Furthermore, the five-tier test format requires not only correct answers but also explanations and visual representations, which adds layers of complexity. Prospective teachers may struggle with articulating their understanding both verbally and visually, especially if they lack confidence or clarity in their knowledge (Taban & Kiray, 2022). Lastly, many prospective primary teachers may have had limited exposure to in-depth science courses during their prior education. This can result in weak foundational knowledge, making it difficult to grasp and effectively communicate complex scientific concepts (Anam et al., 2023).

Visual Representation of Prospective Primary School Teachers on the Concept of Static Electricity

Based on Figure 2, the understanding of static electricity among prospective teachers, as reflected in their drawings, is consistent with the shortcomings observed in their verbal responses. The visual representations created by the candidates reveal similar misconceptions and a lack of scientific accuracy, further emphasizing the gaps in their foundational knowledge of this fundamental physics concept.

The graph depicts a detailed breakdown of potential prospective teachers by gender and high school academic background. The blue bars reflect prospective female teachers who studied science in high school, while the red bars represent prospective male teachers with a similar academic background. The green bars reflect prospective female teachers who did not study science in high school, whereas the purple bars show male prospective teachers in non-scientific fields. This classification provides for a thorough comparison of conceptual knowledge across genders and academic backgrounds.

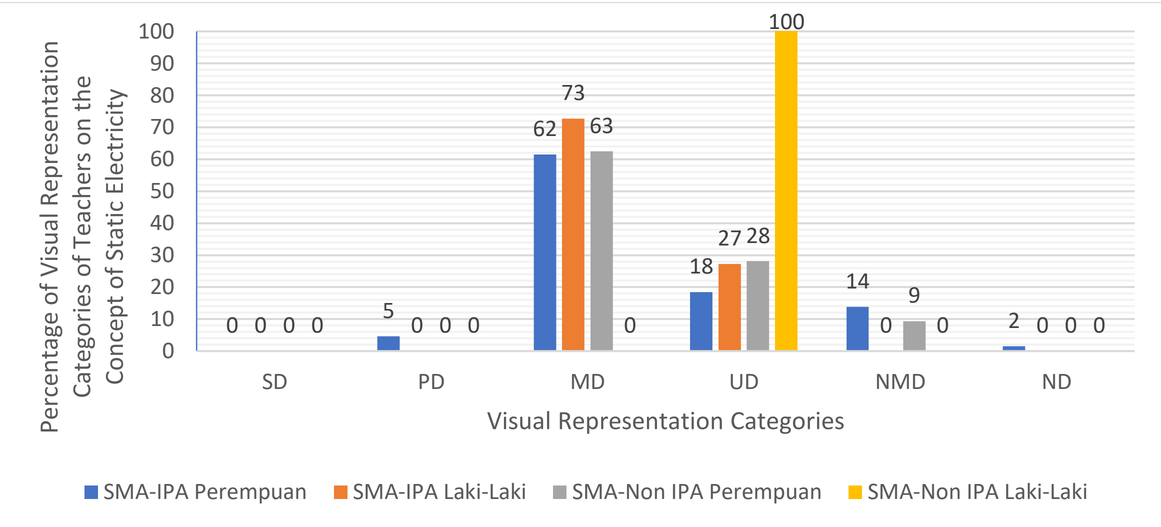

Figure 2. Visual Conception on the Concept of Static Electricity

The first notable finding is that only five prospective teachers produced drawings that reached the Partial Drawing (PD) level. All five of these candidates were female and had a science background from their high school education. This suggests that even among those with more relevant educational backgrounds, a complete and

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accurate understanding of static electricity remains elusive, indicating partial comprehension at best.

The majority of the drawings produced by the prospective teachers demonstrated numerous misconceptions, regardless of the candidates' gender or educational background (science or non-science). This widespread presence of misunderstandings suggests a systemic issue in how static electricity is taught and understood, pointing to the need for more effective instructional strategies that can address and correct these misconceptions comprehensively.

An intriguing finding is that male candidates with non-science backgrounds exhibited a complete lack of ideas when it came to providing answers related to the concept of static electricity. These candidates struggled not only with creating drawings but also with offering verbal explanations, indicating a profound gap in their understanding and ability to engage with the topic.

The difficulty experienced by the prospective teachers in both drawing and verbal explanation of static electricity concepts underscores the complexity of the subject matter. It highlights the challenge of translating abstract scientific concepts into visual and verbal forms, a skill that is essential for effective teaching but appears to be underdeveloped among these candidates.

From a psychological perspective, the difficulty in grasping and conveying the concept of static electricity could be attributed to cognitive load theory (Cheong, Johari, Said, & Treagust, 2015; Doğru, 2021; Maričić, Cvjetićanin, Anđić, Marić, & Petojević, 2024; Taslidere & Yıldırım, 2023). The complexity of the topic may overwhelm the working memory of the candidates, making it difficult for them to process and integrate the information accurately. Additionally, the Dunning-Kruger effect might explain why candidates are confident despite their lack of knowledge, as they may not be aware of the depth of their misunderstandings.

Pedagogically, these findings suggest that current teaching methods may not be effectively fostering deep conceptual understanding (Banawi, Sopandi, Kadarohman, & Solehuddin, 2019; Lukmannudin, Sopandi, Sujana, & Sukardi, 2018; Sukardi, Widodo, & Sopandi, 2017; Sukardi, Widarti, & Nurlela, 2017). Educators should consider employing more interactive and hands-on learning experiences that allow students to experiment with and observe static electricity phenomena firsthand (Altan, Yorulmaz, & Karalar, 2024; Çağlar & Çalik, 2024; Kulaksız & Karaca, 2023; Wang, Yu, Wang, & Chen, 2024; Zaman & Anwar, 2024). Additionally, integrating visual aids and encouraging the practice of drawing scientific concepts can help bridge the gap between abstract ideas and concrete understanding. By addressing these pedagogical shortcomings, we can better equip future teachers with the skills and knowledge needed to effectively teach complex scientific concepts.

The disparity in representational skills between male candidates with non-science backgrounds and female candidates with science backgrounds can be attributed to several factors. Female candidates with a science background likely have had more exposure to scientific concepts and practices, including static electricity, during their education. This prior knowledge provides a foundation that aids in the understanding and representation of scientific concepts (Archila, 2020;

Volkwyn et al., 2020). Additionally, science education often emphasizes visual and hands-on learning experiences that enhance conceptual understanding and representational skills (Matta, 2014). Female candidates with science backgrounds may have benefitted from such approaches more than their non-science counterparts. Furthermore, research has shown that there can be gender differences in learning preferences and strengths, with females often excelling in tasks requiring verbal and visual representation skills (Nitz et al., 2014). This might explain why female candidates are better at translating abstract concepts into drawings and explanations. Lastly, self-efficacy plays a crucial role in performance. Candidates with a science background, who have previously succeeded in related subjects, might have higher confidence in their abilities to understand and represent scientific concepts (Atakan & Akçay, 2024). This confidence can lead to better performance compared to those who lack such background and confidence.

4. Conclusion

The study highlights widespread misconceptions about static electricity among prospective elementary school teachers, revealed through verbal and visual assessments using a five-tier test, regardless of gender or educational background. Candidates, especially those with non-science backgrounds, struggle with cognitive and educational challenges, indicating gaps in current teaching approaches. To address these issues, teacher education programs must adopt interactive, hands-on, and visually engaging strategies to enhance understanding and teaching effectiveness. However, limitations such as a small sample size, limited generalizability, and the constraints of the five-tier test suggest the need for broader assessment tools in future research.

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