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Research Article

Examining the Relationship Between Age and Misconceptions in Electricity among Secondary School Students and the Moderating Role of Gender

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Abstract
Understanding electricity concepts, such as circuits, current, and voltage, presents significant difficulties for secondary school students due to their abstract nature and associated misconceptions. This study examines the relationship between age and misconceptions in understanding these concepts, as well as the moderating role of gender. A cross-sectional, quantitative research design was adopted, utilizing the Electricity Diagnostic Test (EDT) to evaluate 298 secondary school students. The findings reveal no significant relationship between age and misconceptions, indicating that conceptual misunderstandings persist across different age groups. Additionally, gender does not significantly moderate this relationship, suggesting that both male and female students face similar difficulties in learning electricity concepts. These results challenge traditional cognitive development theories, such as Piaget's, which propose that older students should have a better grasp of abstract concepts. Instead, the findings align with research indicating that misconceptions in physics persist due to instructional methods rather than age-related cognitive development. The study highlights the importance of adopting evidence-based teaching strategies, such as interactive learning and conceptual change approaches, to address misconceptions. This research contributes to physics education by emphasizing the need for gender-inclusive pedagogies and targeted interventions that focus on addressing misconceptions rather than assuming natural conceptual progression. The findings have practical implications for educators and policymakers, advocating for curriculum adjustments that integrate diagnostic assessments and active learning methodologies to enhance conceptual understanding in electricity. Future research should explore additional socio-cultural factors influencing physics learning and assess the long-term impact of instructional interventions on conceptual retention.

Keywords: Age, Electricity Concepts, Gender, Learning Difficulties, Misconceptions, Physics Education

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1. INTRODUCTION

Understanding the concepts of electricity, such as electric circuits, current, and voltage, poses significant challenges for secondary school students due to their abstract and non-intuitive nature. The ability to grasp these concepts is influenced by numerous factors, including students' age, gender, and pre-existing misconceptions, as well as external factors such as instructional design and social context. Research rooted in cognitive development theories, like Piaget's stages, suggests that younger secondary school students, especially those aged 11–13, may struggle to engage with these abstract topics because they rely on concrete operational thinking, which limits their ability to handle scientific abstractions (Johansson & Rengman, 2010; Olaniyan & Govender, 2018). Older students, with more advanced formal thinking abilities, are better equipped to process the abstract reasoning required for understanding concepts such as current flow and resistance (Tan, Ahmad, & Others, 2020). However, the relationship between age and concept understanding may not be linear, as cognitive challenges stemming from misconceptions remain pervasive across all age levels, even into later stages of formative education (Shipstone, 1988; Sencar & Eryılmaz, 2004). These challenges emphasize the importance of studying the interaction of age with other critical variables, including gender and misconceptions.

Gender inequalities in science education, particularly in physics topics such as electricity, have been consistently highlighted in educational research. Boys tend to demonstrate higher self-efficacy and interest in electricity-related tasks, which can lead to their overconfidence during hands-on activities, while girls often experience lower self-confidence despite performing equally well in assessments (Sencar & Eryılmaz, 2004; Tan et al., 2020). Societal norms and stereotypes portraying physics as a male-dominated domain further influence these disparities, reducing girls' interest and participation (Chambers & Andre, 1997; Mackay & Parkinson, 2010). These gender-based barriers are particularly evident in collaborative classroom scenarios, where boys are more likely to dominate discussions and experimental setups, thereby pushing girls into passive roles. An important observation is that teaching strategies such as STEAM-integrated approaches and collaborative learning can successfully address some elements of gender disparity. A study by Tan et al. (2020), for instance, demonstrated that utilizing Scratch to design games and animations related to electricity concepts equally enhanced the learning achievements of both boys and girls, effectively reducing the gender gap. Meanwhile, structured hands-on approaches, such as problem-solving or project-based learning, have been shown to improve self-efficacy among girls and support their ability to overcome misconceptions (Olaniyan & Govender, 2018; Nwalo & Eze, 2021).

In addition to gender, misconceptions create further obstacles for students in understanding electricity concepts. Abstract topics such as circuits place significant cognitive demands on working memory, reasoning, and logical sequencing areas where students with diagnosed difficulties, such as dyslexia or ADHD, often struggle (Olaniyan & Govender, 2018; Sencar & Eryılmaz, 2004). Unfortunately, misconceptions are frequently under-researched in the context of gender, with existing studies tending to focus either on broader struggling student populations or general gender disparities without considering the compounded impact of both factors. This leaves a gap in understanding how gender may moderate the educational experiences of students who also face these cognitive challenges. Research suggests that girls with misconceptions are less likely to be identified for additional support and more likely to remain in classrooms that do not tailor materials to their needs (Chambers & Andre, 1997; Olaniyan & Govender, 2018). Furthermore, schools often rely on traditional, lecture-oriented instructional methods that disproportionately disadvantage learners with cognitive challenges, with boys more often being referred to specialized pathways or programs for remediation (Mackay & Parkinson, 2010).

Despite these challenges, innovative teaching strategies have offered promising pathways to bridge gaps caused by both gender and misconceptions. Recent studies highlight how constructivist and inquiry-led approaches help mitigate disparities by actively engaging learners of varying skill levels. Using inclusive strategies such as conceptual change texts, researchers like Chambers and Andre (1997) illustrated how interest, prior exposure, and structured visual materials reduced both misconceptions and gender-related gaps during electricity instruction. Additionally, collaborative and task-based approaches detailed by Nwalo and Eze (2021) revealed that active project or demonstration-based experiences improved long-term knowledge retention, particularly for underperforming or disengaged groups of students, including females. Interactive STEAM platforms, as described by Tan et al. (2020), further build on these strategies by employing creative media to equalize engagement and promote gender-neutral opportunities.

Nonetheless, gaps remain in combining these insights to fully understand the tripartite interaction of age, gender, and complex learning needs in the context of electricity education. While studies like those by Sencar and Eryılmaz (2004) and Johansson and Rengman (2010) address some dimensions of age-related conceptual challenges, they often fail to consider how gendered socialization or self-perceptions influence the progression of students' understanding over time. Similarly, although innovative pedagogies aimed at narrowing gender gaps show success in standalone research, their integration with more targeted interventions for younger learners or those with misconceptions is underexplored. Moreover, while the general efficacy of STEAM-based and collaborative methods is acknowledged, these approaches require further validation across diverse educational contexts and demographic groups. Investigating these interrelations is crucial for developing instructional designs that cater not only to age and ability differences but also to the moderating influences of gender on how students navigate abstract scientific principles.

1.1. Literature Review

Understanding the interplay between age, gender, and misconceptions in conceptualizing electricity concepts in secondary schools has been a growing area of research in recent years. There is increasing recognition that gender acts as a moderating factor in shaping student engagement, achievement, and retention in physics-related subjects, particularly in heavily abstract topics such as electricity. Several studies have explored this dynamic by incorporating modern educational strategies, statistical modeling, and innovative pedagogical tools to address persistent disparities.

Recent studies have established that gender plays a significant role in shaping students' experiences and outcomes in learning electricity. Research by Tan et al. (2020) highlights how a STEAM-integrated approach utilizing Scratch programming significantly reduced gender disparities in students' achievement in electricity. By framing the learning experience within a creative and interactive context, the study demonstrated that both male and female students exhibited similar levels of improvement in conceptual understanding. Such findings underscore the potential of innovative instructional methods in mitigating longstanding gaps linked to societal and self-efficacy biases. Similarly, Olaniyan and Govender (2018) explored collaborative learning techniques as an intervention. They found that group-based problem-solving strategies, such as Polya's problem-solving method, enhanced both male and female students' performance in electricity. Their research showed that females benefited disproportionately from the intervention when compared to traditional teaching methods, thereby narrowing the gender achievement gap in electricity-related topics. This aligns with broader observations that structured, hands-on methodologies can effectively challenge male-dominated classroom dynamics and stereotypes.

The role of gender-related self-efficacy has also been explored extensively in this context. Studies continue to find that boys often report higher self-confidence in addressing physics problems, influenced by greater informal exposure to technology and societal norms that present science as a male-oriented domain. For instance, research by Nwalo and Eze (2021) reaffirms that teaching methods involving project-driven approaches contribute significantly to reducing disparities. When students engaged in collaborative or immersive tasks, females reported greater retention of abstract physics concepts like circuits and voltage. These findings suggest that pedagogical approaches that emphasize active participation, especially through project and task-based methods, can counterbalance gender inequality exacerbated by societal norms. However, gaps remain in investigating how early these disparities can emerge and the role of developmental cognitive differences, particularly for younger students.

Age, particularly the developmental stage, also interacts with gender in shaping understanding and achievement in electricity. Tan et al. (2020) emphasize that younger secondary school students may face unique challenges due to cognitive developmental stages, with self-efficacy issues for girls often exacerbating these struggles. This finding correlates with a long-standing acknowledgement in education research that abstract topics such as electric circuits are more cognitively demanding for younger students, who often rely on concrete representations over abstract reasoning. Introducing gender-responsive and visually interactive tools for younger students may help address these barriers. While the STEAM-based Scratch approach was presented as a promising intervention, more contextually relevant examples addressing different age groups have yet to be explored in similar capacities.

Compounding these challenges for many students are misconceptions, such as working memory deficits, ADHD, or specific reading challenges like dyslexia. Researchers such as Olaniyan and Govender (2018) note how collaborative learning and structured instructional strategies help mitigate the cognitive load required to process abstract physics concepts. Yet, there is a notable limitation in literature addressing the combined effects of age, gender, and learning impairments within this specific context. While the referenced studies emphasize the improvements for female students resulting from equity-driven pedagogies, they lack targeted research directed at students with diagnosed misconceptions. This gap highlights a critical area for further exploration, especially to disentangle how gender moderates the compounded effects of cognitive challenges and developmental factors in electricity learning.

Across these studies, misconceptions about electricity concepts persist as a universal barrier to understanding. Students often harbor preconceptions, such as the notion that current is "consumed" or that circuits are "unidirectional," which inhibit their ability to develop scientifically accurate mental models. Gender, as a moderator, further defines how misconceptions evolve or are resolved. For instance, Olaniyan and Govender (2018) observed that while both male and female students begin with substantial misconceptions, females often resolve conceptual difficulties more effectively in collaborative learning contexts. Tan et al. (2020) further found that integrating creative digital tools allowed both genders to overcome misconceptions with comparable success rates, thereby addressing gendered patterns linked to self-confidence and engagement. These advances suggest that cognition-based teaching interventions can complement gender-focused teaching strategies to dismantle pre-existing misunderstandings in electricity.

Still, innovative teaching methods have proven effective in bridging gaps in gendered participation and learning outcomes. Tan et al. (2020) demonstrated how creative problem-solving techniques and multimedia platforms encouraged active student engagement, reducing traditional confidence divides. These findings align closely with observations by Nwalo and Eze (2021), who found that project-based learning pedagogies successfully tackled gender biases in science. Nwalo and Eze's findings further emphasize that these hands-on approaches are particularly beneficial for female students and encourage greater statewide adoption of gender-sensitive tools to counteract self-efficacy declines in STEM-related subjects. Nonetheless, evidence-specific approaches that consider the developmental and conceptual contours of electrical engineering education for males and females are necessary.

While the highlighted studies provide varied insights into effective teaching practices and the role of gender in mitigating disparities in electricity learning, they collectively signal a broader gap in integrated research. Despite repeated acknowledgement of gender as a critical moderating variable, the combined impacts of age, gender, and misconceptions remain insufficiently addressed in recent literature. For educators and policymakers seeking to develop holistic strategies, bridging these gaps will require the inclusion of multimodal interventions sensitive to developmental stages, cognitive barriers, and the socio-cultural realities that shape self-perception along gender lines. These dimensions remain critical to undoing persistent inequalities and ensuring all students are equipped to conceptualize abstract scientific principles like electricity effectively.

1.2. Research Questions

1. What is the relationship between age and misconceptions in secondary school students?
2. To what extent does age predict misconceptions in secondary school students?
3. Does gender moderate the relationship between age misconceptions?

2. METHODOLOGY

2.1. Research design

This study adopts a quantitative, correlational research design with a cross-sectional approach to explore the relationship between age and misconceptions in understanding electricity concepts among secondary school students and to determine whether gender moderates this relationship. The design focuses on examining naturally occurring relationships without manipulating variables, making it suitable for assessing how age influences misconceptions and how gender interacts with this relationship. This design ensures a systematic investigation of the research questions and provides insights into the interplay between age, gender, and misconceptions.

2.2. Sample and Sampling techniques

The sample for this study consisted of 10 secondary schools selected from the local government area. A purposive sampling technique was used to choose schools that offered physics as a subject and had a sufficient mix of male and female students, aligning with the study's focus. Within each selected school, a maximum of 30 students participated in the study. Due to differences in the number of male and female students, quota sampling was employed to ensure adequate representation of both genders in the sample. To guarantee that both groups were adequately represented for comparative analysis, a fixed number of male and female students were chosen depending on their availability in each institution.

2.3. Research Instrument

The research instrument employed for this study was the Electricity Diagnostic Test (EDT), adapted from Adeduyigbe et al. (2024). Section A collected demographic information such as school name, gender, age, and class, facilitating the investigation of the influence of age and gender on students' misconceptions. Section B comprised eight diagnostic items specifically addressing misconceptions in electricity concepts. Each diagnostic item in Section B was structured as a two-tier question. The first tier featured eight multiple-choice questions with three answer options, including one correct response and two distractors. The second tier provided four explanation options for the chosen answer: two incorrect explanations, one valid explanation, and an option for students to provide their reasoning if they disagreed with the provided explanations.

Scoring for the EDT, awarded a maximum of two marks per item. Students earned one mark for selecting the correct answer in the first tier and another mark for providing the correct justification in the second tier. If the first-tier answer was incorrect, no marks were awarded for the second tier, even if the justification was valid. This scoring approach ensured an accurate assessment of both content knowledge and reasoning, enabling a comprehensive evaluation of students' misconceptions in electricity concepts.

2.4. Validity of the Instrument

The Electricity Diagnostic Test (EDT) was approved by a panel of two experienced physics instructors and two science education specialists to ensure a thorough assessment. Their expertise in physics teaching and assessment design led to their selection.

The experts assessed the EDT items using specific validation criteria, including the following:

1. Validity of Content: ensuring that all significant electrical topics that are relevant to the secondary school curriculum are covered in detail in the test questions.
2. Clarity: Assessing whether the questions are clear, simple, and appropriately phrased for the students who are the intended audience.
3. Relevance: Assessing each question's contribution to the goal of identifying learning challenges.

The EDT was iteratively revised in response to their input, which included clearing out any potential ambiguities, strengthening sentence structures for improved comprehension, and rewording questions for clarity.

2.5. Reliability of the Instrument

To guarantee reliable and accurate measurement, the Electricity Diagnostic Test (EDT) was put through a reliability test using the test-retest technique. Twenty (20) Senior Secondary School II (SSS II) students were chosen using a purposive sampling technique to take the test in its first delivery. The study's target population consisted of these pupils. To compare the outcomes over time, the same set of students completed the test once more after a week. The Pearson Product-Moment Correlation (PPMC) algorithm was used to examine the data gathered from both administrations. An adequate degree of dependability for the EDT instrument was shown by the computed reliability coefficient, which was $r = 0.71$.

2.6. Method of Data Analysis

The data analysis for this study will include three main statistical tests. First, the Pearson Product-Moment Correlation (PPMC) will assess the relationship between age and misconceptions. Simple Linear Regression will determine how well age predicts misconceptions, with age as the independent variable, and Moderated Multiple Regression will evaluate whether gender moderates this relationship by including age, gender, and their interaction term as predictors. Statistical significance will be set at the 0.05 level, with results interpreted based on coefficients, R^2 values, and p-values.

3. FINDINGS

Research Question 1: What is the relationship between age and misconceptions in secondary school students?

The findings indicate that there is no significant relationship between age and misconceptions among secondary school students, as measured by the total score. The Pearson correlation coefficient ($r = 0.010$) suggests a negligible positive relationship between the two variables, which is not statistically significant (p=0.864, p>0.05). This implies that age does not meaningfully influence misconceptions in this context, and any observed association is likely due to random variation rather than a genuine effect.

Table 1. Correlations

		Total_score	SMEAN(Age)
Total_score	Pearson Correlation	1	.010
	Sig. (2-tailed)		.864
	N	298	298
(Age)	Pearson Correlation	.010	1
	Sig. (2-tailed)	.864	
	N	298	298

Research Question 2: To what extent does age predict misconceptions in secondary school students?

The findings indicate that age does not significantly predict misconceptions among secondary school students. The regression analysis revealed an R^2 value of 0.000, indicating that age explains virtually none of the variation in misconceptions (Total Score). The regression model was not statistically significant, F(1,296)=0.029, p=0.864, suggesting that age does not contribute meaningfully to predicting misconceptions. Additionally, the unstandardized coefficient for age (B=0.014) indicates a negligible positive effect of age on misconceptions, but this effect is not statistically significant (p=0.864). The 95% confidence interval for the slope further confirms that the relationship is not meaningful.

Table 2. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.010[a]	.000	-.003	2.181

a. Predictors: (Constant), (Age)

Table 3. ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.139	1	.139	.029	.864[b]
	Residual	1407.703	296	4.756		
	Total	1407.842	297			

a. Dependent Variable: Total_score
b. Predictors: (Constant), (Age)

Table 4. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.228	1.320		3.203	.002
	(Age)	.014	.082	.010	.171	.864

a. Dependent Variable: Total_score

Research Question 3: Does gender moderate the relationship between age and misconceptions?

Visually, the chart suggests that gender may moderate the relationship between age and misconceptions. Male students appear to show a sharper increase in misconceptions as they age, particularly between ages 11–13, while female students show a more stable trend. However, this observation therefore needs to be confirmed through statistical analysis.

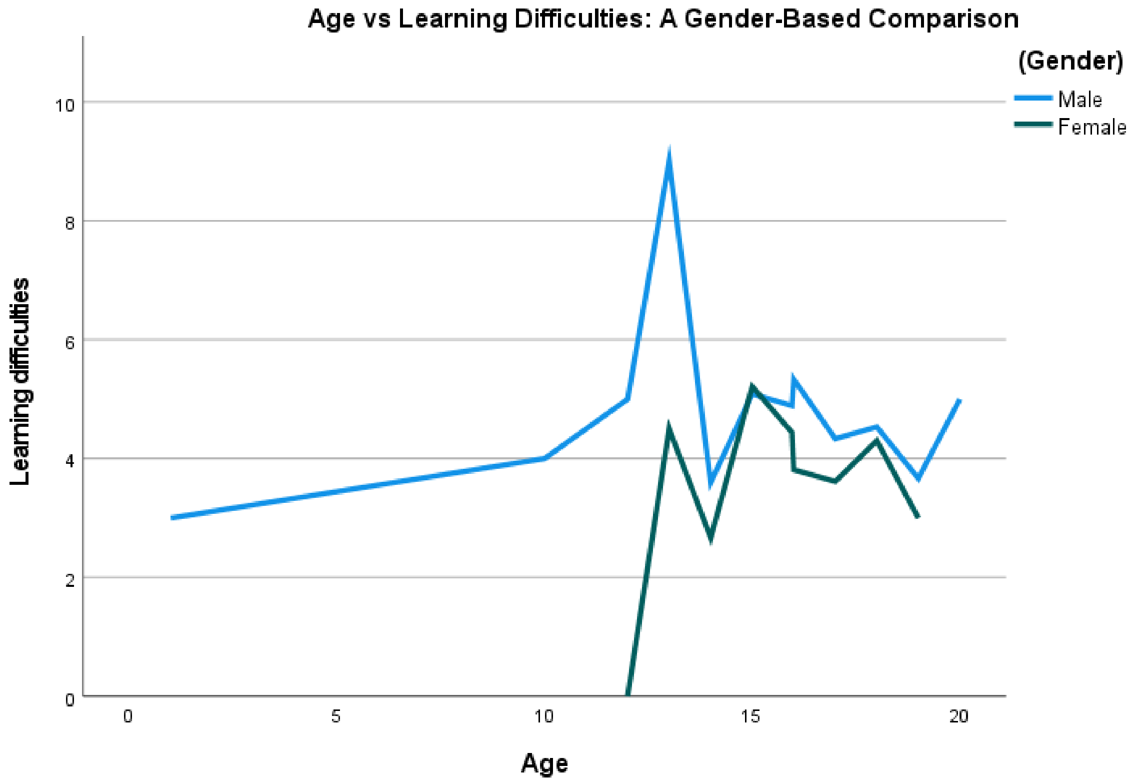

Figure 1. Age vs misconceptions: A Gender-Based Comparison

Table 5. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.167[a]	.028	.018	2.158

a. Predictors: (Constant), Interaction, (Age), (Gender)

Table 6. ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.142	3	13.047	2.803	.040[b]
	Residual	1368.701	294	4.655		
	Total	1407.842	297			

a. Dependent Variable: Total_score
b. Predictors: (Constant), Interaction, (Age), (Gender)

Table 7. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Constant	5.010	3.999		1.253	.211
	Age	.030	.249	.021	.122	.903
	Gender	-.647	3.036	-.147	-.213	.831
	Interaction	-.005	.189	-.020	-.028	.977

a. Dependent Variable: Total_score

The moderated multiple regression analysis reveals that the model, Age, Gender, and their interaction, accounts for approximately 2.8% of the variance in misconceptions ($R^2 = 0.028$), with a statistically significant overall model ($F(3, 294) = 2.803$, $p = .040$). However, the individual predictors are not statistically significant: Age ($p = .903$), Gender ($p = .831$), and the Age × Gender interaction ($p = .977$). This indicates that neither Age, Gender, nor their interaction significantly predicts misconceptions in this sample. Therefore, other variables may be more influential in explaining the variance in misconceptions.

4. DISCUSSION

This study investigated the influence of age, gender, and misconceptions on secondary school students' understanding of electricity concepts. The findings revealed that there was no significant relationship between age and misconceptions, suggesting that conceptual challenges in electricity persist across different age groups. Additionally, gender did not significantly moderate this relationship, indicating that both male and female students face similar difficulties in understanding electricity concepts. These results provide valuable insights into the factors influencing physics learning and have important implications for instructional practices and policy decisions.

The findings of this study challenge traditional cognitive development theories, such as Piaget's (1954) theory, which suggests that older students should have a better grasp of abstract scientific concepts due to their transition into formal operational thinking. The results align with previous research indicating that misconceptions in physics are deeply ingrained and persist across different age groups (Shipstone, 1988; Sencar & Eryılmaz, 2004). This suggests that rather than age alone determining students' conceptual understanding, instructional strategies and prior knowledge play a more significant role. The persistence of misconceptions across age groups highlights the need for targeted instructional interventions that directly address common misunderstandings in electricity.

Moreover, the lack of a significant moderating effect of gender on misconceptions contrasts with previous studies that suggest boys tend to exhibit higher confidence and engagement in physics-related tasks (Chambers & Andre, 1997; Mackay & Parkinson, 2010). While some literature reports that male students often outperform their female counterparts due to greater exposure to technology and societal reinforcement (Tan et al., 2020), the current findings indicate that when assessed using a structured diagnostic framework, both genders struggle equally with electricity concepts. This finding aligns with studies suggesting that instructional methods, classroom participation, and access to hands-on activities play a more critical role in shaping students' physics learning outcomes than gender alone (Olaniyan & Govender, 2018).

The study's results further indicate that gender disparities in physics learning may be context-dependent. While some studies have found that male students are more confident and dominant in practical physics activities (Mackay & Parkinson, 2010), this study's use of a structured diagnostic test minimized external factors such as classroom participation dynamics. This highlights the importance of designing assessments and instructional strategies that provide equal opportunities for all students to demonstrate their understanding without the influence of social biases.

The findings of this study suggest several practical applications for educators and policymakers in improving physics education:

- Curriculum Adaptation: Given that misconceptions persist across age groups, curriculum developers should incorporate misconception-focused teaching strategies, such as conceptual change texts and interactive simulations, to address persistent misunderstandings in electricity concepts (Nwalo & Eze, 2021).
- Instructional Strategies: Educators should implement active learning methodologies, including peer instruction, collaborative problem-solving, and inquiry-based experiments, to enhance conceptual understanding and promote student engagement (Olaniyan & Govender, 2018).
- Gender-Inclusive Pedagogies: Although no significant gender effect was found, physics teachers should ensure equitable classroom participation by using structured group discussions and problem-solving teams to prevent gender-based disengagement (Tan et al., 2020).

- Professional Development for Teachers: Teacher training programs should emphasize the use of diagnostic assessment tools to identify and address students' misconceptions in physics. Workshops on implementing formative assessments and real-time feedback mechanisms can help educators tailor their teaching to students' needs.
- Policy Recommendations: Policymakers should consider integrating adaptive learning technologies in physics education, allowing for personalized instruction that caters to individual student needs. Additionally, structured intervention programs targeting foundational misconceptions should be introduced at earlier stages of secondary education.

5. CONCLUSION

This study provides new insights into how age, gender, and misconceptions influence students' understanding of electricity concepts. Contrary to traditional cognitive development theories, the findings indicate that misconceptions in electricity persist across different age groups, reinforcing the idea that instructional methods play a more significant role than age alone in shaping students' conceptual understanding. Additionally, the absence of significant gender effects highlights the importance of equal access to structured, diagnostic assessments and active learning strategies to support all students in overcoming misconceptions in physics. Building on previous research (Shipstone, 1988; Sencar & Eryılmaz, 2004; Olaniyan & Govender, 2018), this study underscores the importance of targeted instructional strategies that address misconceptions directly rather than relying solely on developmental progression. The findings also contribute to the growing body of literature advocating for gender-inclusive pedagogies in science education (Chambers & Andre, 1997; Tan et al., 2020).

The study's contributions to science education extend beyond identifying conceptual challenges—it provides evidence supporting the integration of active learning, collaborative problem-solving, and diagnostic assessments to enhance student engagement and conceptual understanding. Policymakers and educators should prioritize these approaches in curriculum development to ensure a more inclusive and effective learning environment for all students.

6. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This research was carried out among secondary school students in the Ondo West Local Government Area of Nigeria, employing purposive and quota sampling techniques to ensure a representative sample. A total of 237 students from 10 different schools participated in the study, but this relatively small sample size may pose challenges in generalizing the findings to a broader context. Variations in school resources, instructional approaches, and curriculum implementation across different regions could significantly impact students' understanding of electricity concepts. To enhance the validity and applicability of future research, it would be beneficial to include larger and more diverse samples from various geographical regions. Furthermore, expanding the scope of the study to encompass students with a range of cognitive abilities and socio-economic backgrounds could yield valuable insights. Such an approach would help to better understand how factors like age, gender, and misconceptions interact to influence physics education outcomes.

The following recommendations were made based on the findings in this research paper:

- Investigate Longitudinal Effects of Age and Gender on Misconceptions: Future studies should adopt a longitudinal design to explore how the interplay of age, gender, and misconceptions evolves over time. This would provide insights into developmental changes and long-term outcomes related to understanding abstract scientific concepts like electricity.
- Examine Intersectionality in Learning Barriers: Researchers should delve deeper into the intersectionality of factors such as gender, socio-economic status, and specific misconceptions to understand how these variables jointly influence students' engagement and performance in physics.
- Evaluate the Effectiveness of Inclusive Instructional Methods: Further research is needed to assess the impact of innovative teaching strategies, such as STEAM-integrated approaches and collaborative learning models, across different demographic groups. This can inform best practices for reducing misconceptions and enhancing engagement in physics.

- Explore Early Intervention Strategies: Studies should focus on the effectiveness of early intervention programs aimed at addressing misconceptions and misconceptions in electricity concepts at lower secondary school levels. This can help identify the optimal timing and methods for support.
- Assess Cultural and Social Influences: Additional research should examine how cultural norms and societal stereotypes about gender roles in science education affect learning outcomes. Understanding these influences can help design strategies to foster equitable learning environments.
- Develop Adaptive Diagnostic Tools: Researchers should work on refining and testing diagnostic tools like the ELDDT to ensure they are adaptive and inclusive for students with varying abilities and backgrounds. Such tools should also be validated for use in diverse educational contexts.
- Study Technology Integration in Physics Education: Investigate how digital platforms and interactive technologies, such as simulations or gamified learning, impact the understanding of complex physics concepts across age and gender groups.
- Investigate Teacher Preparedness and Perceptions: Future studies should explore teachers' preparedness and attitudes toward addressing age, gender, and misconceptions in physics education. This will help identify gaps in teacher training and professional development.

By addressing these areas, researchers can contribute to a deeper understanding of the factors affecting learning outcomes in physics and inform evidence-based strategies to improve student performance and engagement.

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Research Ethics. Ethical approval for this study was obtained from the appropriate school authorities, who granted permission for the research to be conducted within their institutions. Prior to data collection, the purpose of the study was clearly explained to the participating students. Their voluntary participation was emphasized, and informed consent was obtained. To ensure confidentiality, all personal identifiers were removed, and participants' responses were treated with strict anonymity. The data collected were used solely for academic purposes and handled in accordance with ethical research standards.

Data Availability Statement. The only data available for this study are those presented within the article. No additional data are available.

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