International Journal of Didactical Studies
Onlinefirst Article, 2026
https://doi.org/10.33902/ijods.202637563

Research Article

A quasi-experimental study of Ausubel's advance organizers, algebra performance, and gender differences among senior secondary students

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Senior secondary school students in Nigeria continue to experience challenges in learning algebra, a core component of mathematics critical for advancement in science, technology, engineering, and mathematics fields. Traditional lecture-based instruction often fails to support students' conceptual understanding, highlighting the need for more cognitively grounded approaches. Ausubel's Advance Organizers were introduced in this study as instructional tools designed to activate prior knowledge and promote meaningful learning. The study adopted a quasi-experimental design involving senior secondary school students from two public schools in Nigeria to investigate the effect of the strategy on students' performance in algebra and to determine whether gender influenced the outcomes. Findings revealed that students taught with Advance Organizers performed better in algebra than those taught using conventional methods. Moreover, no significant gender differences were observed, suggesting that the strategy was equally effective for both male and female students. The study concludes that Advance Organizers can serve as an equitable and effective teaching approach for improving algebra learning among secondary school students. It further emphasizes the importance of context-responsive instructional practices in enhancing mathematics education across sub-Saharan Africa.

Keywords: Advance organisers; Algebra instruction; Gender differences; Mathematics performance; Nigerian classrooms; Secondary education

Article History: Submitted 11 July 2025; Revised 3 November 2025; Published online 5 May 2026

1. Introduction

Mathematics remains a cornerstone of educational advancement and national development, particularly because of its foundational role in science, technology, engineering, and mathematics [STEM]. In Nigeria, mathematics education is recognized as essential for preparing learners to participate effectively in a rapidly changing global economy (Nigerian Educational Research and Development Council, 2012). However, persistent underperformance especially in algebra continues to limit students' success and long-term engagement with STEM fields. Studies have shown that many senior secondary school students possess limited conceptual understanding of algebraic principles and rely heavily on rote memorization (Guo et al., 2023; Patel & Trivedi, 2020). These difficulties are compounded by inadequate teacher preparation, insufficient instructional resources, and a lack of professional development opportunities, which together hinder the adoption of learner-centred approaches. Consequently, students often find it difficult to connect

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How to cite: Ezumezuh, G. M., Eze, C., Danlami, K. B. (2026). A quasi-experimental study of Ausubel's advance organizers, algebra performance, and gender differences among senior secondary students. *International Journal of Didactical Studies.* Advance online publication. https://doi.org/10.33902/ijods.202637563

algebraic concepts with real-world applications, resulting in low achievement and declining interest in mathematics (Arthur et al., 2018; Booth et al., 2015).

Teaching algebra effectively presents unique pedagogical challenges. Many learners struggle with the abstract nature of symbols and logical structures, leading to fragmented understanding and reliance on procedural rules rather than conceptual reasoning (Bozkuş et al., 2025; Moralı & Filiz, 2023; Mpuangnan et al., 2024). Teacher-centred instructional approaches, which dominate Nigerian classrooms, tend to emphasize memorization and procedural fluency at the expense of conceptual development. In contrast, cognitively oriented instructional approaches can promote more active engagement, evidence-based reasoning, and stronger conceptual understanding, particularly when they incorporate inquiry, discussion, and structured explanation (Altunışık et al., 2023; Dereje, 2023; Tshering et al., 2024; Wangmo et al., 2025). Strategies such as inquiry-based learning, visual modelling, and collaborative problem-solving have proven effective in strengthening students' understanding of algebraic ideas and enhancing motivation to learn mathematics.

One promising cognitive strategy is Ausubel's Advance Organizers, rooted in the theory of meaningful learning, which emphasizes linking new knowledge to existing cognitive structures (Ausubel, 1960). Advance Organizers are pre-instructional tools that provide conceptual frameworks before new material is introduced, thereby helping learners integrate prior knowledge with new information. In mathematics education, these organizers serve as cognitive scaffolds that improve comprehension and retention, especially in topics that students typically find abstract, such as algebra. Research has shown that Advance Organizers enhance students' academic performance, stimulate curiosity, and promote meaningful engagement in learning (Guo et al., 2023).

Despite their potential, the application of Advance Organizers in Nigerian mathematics classrooms remains limited and inconsistently studied. Existing research often suffers from methodological constraints, such as small sample sizes, limited control of variables, and insufficient attention to contextual factors like gender and socio-economic background. Moreover, gender differences in mathematics achievement remain a critical yet unresolved issue. While some studies have found that male students outperform females (Tarfa & Dike, 2022), others report negligible or context-dependent differences (Vlach & Sandhofer, 2011). These mixed findings highlight the influence of classroom dynamics, cultural expectations, and unequal access to learning resources on students' engagement and achievement (Awofala & Lawani, 2020).

Addressing these complexities requires strategies that not only improve learning outcomes but also promote equity in mathematics classrooms. Advance Organizers, by encouraging active participation and linking prior knowledge with new ideas, may help bridge gender gaps in mathematics performance. However, empirical evidence on their effectiveness across gender lines in Nigerian secondary schools remains scarce. This study therefore investigates the effect of Advance Organizers on students' performance in algebra and examines whether gender influences the observed outcomes.

The study is guided by the following research questions:

RQ 1) How does the performance of senior secondary school students taught algebra using Advance Organizers compare to those instructed through conventional methods?

RQ 2) What differences exist in the performance of male and female students when taught algebra using Advance Organizers compared to the conventional method?

2. Literature Review

2.1 Algebra in Secondary School Mathematics

Algebra constitutes a foundational domain in secondary school mathematics, critical not only for its procedural utility but also for its role in fostering abstract reasoning, generalisation, and problem-solving skills. Globally, the acquisition of algebraic proficiency has been recognised as essential for success in mathematics and science-related disciplines. However, students often struggle with core algebraic concepts, as evidenced by persistent underperformance across national and international assessments (Imasuen & Stanley, 2022; Niringiyimana & Maniraho, 2023). These learning difficulties are not limited to procedural fluency but extend to conceptual understanding and the ability to apply algebra in unfamiliar contexts. Efforts to reform algebra curricula in various countries have yielded mixed results. In Ireland, for example, the introduction of a functions-based curriculum model was intended to deepen students' understanding of algebra through structural connections. Yet, research shows that such curriculum innovations have not significantly enhanced students' technical algebraic skills, due in part to inconsistencies between intended curricula and actual classroom implementation (Prendergast & Treacy, 2018). This disconnect highlights a

broader issue in mathematics education: reform efforts often falter when pedagogical practices are not adequately aligned with curricular objectives.

To address students' difficulties, recent studies have emphasised the importance of adopting student-centred and cognitively demanding instructional strategies. Interactive lessons that integrate visualisation, real-life contexts, and exploratory tasks have shown promise in improving students' engagement, motivation, and conceptual grasp of algebraic principles (Botuzova & Nichyshyna, 2023; Sansyzbayeva et al., 2024). The pedagogical choices made by teachers, particularly in the selection and sequencing of examples, have also been found to significantly influence the depth of student learning. As Henríquez-Rivas and Verdugo-Hernández (2024) argue, carefully constructed examples can support students in transitioning from procedural manipulation to meaningful algebraic reasoning. Moreover, the integration of algebra with other mathematical domains has gained traction as a strategy for enhancing learning coherence. Intra-subject approaches, such as linking algebra with geometry or statistics, have been associated with increased student interest and a more connected understanding of mathematical concepts (Botuzova & Nichyshyna, 2023). These integrated approaches are particularly relevant in secondary education, where compartmentalised teaching often limits students' ability to see mathematics as an interconnected whole.

A growing body of literature also underscores the importance of bridging the gap between school and university-level algebra. Initiatives aimed at aligning secondary algebra curricula with abstract algebra at the tertiary level can enrich students' understanding and better prepare them for advanced studies (Shamash, 2019; Suominen, 2018; Veith et al., 2022). This vertical alignment is especially important for pre-service teachers, who must develop both pedagogical content knowledge and a deep conceptual understanding of algebra to be effective in the classroom. Despite these advances, certain gaps remain in the literature. There is limited empirical research on how these instructional innovations perform in under-resourced and culturally diverse contexts, particularly in sub-Saharan Africa. While existing studies offer valuable insights into effective strategies, there is a need to investigate how socio-cultural, linguistic, and infrastructural factors mediate students' experiences with algebra. Furthermore, inconsistencies in teachers' preparation and pedagogical orientation continue to undermine efforts to reform algebra instruction at the classroom level.

2.2. Challenges of Teaching and Learning Algebra

The teaching and learning of algebra continue to pose significant challenges globally. A combination of cognitive, pedagogical, and systemic barriers contributes to students' persistent difficulties in developing a deep understanding of algebraic concepts. Foundational among these challenges is students' lack of prior mathematical knowledge, which hampers their ability to engage with abstract algebraic representations and operations (Herscovics, 2018; Warren et al., 2016). Cognitive overload, particularly in transitioning from arithmetic to algebra, often results in misconceptions and fragmented understanding, especially when learners are not adequately supported through concept-building instructional strategies. Traditional instructional approaches remain a major obstacle to effective algebra education. Many classrooms rely heavily on procedural teaching and rote memorisation, which tend to prioritise symbolic manipulation over conceptual comprehension (Kaput, 2017; Walkoe, 2015). Such methods can limit students' ability to reason algebraically, recognise patterns, and apply knowledge to novel situations. The overemphasis on symbolic rules, divorced from meaningful contexts, undermines opportunities for students to develop flexible and adaptive algebraic thinking. These challenges are further magnified in resource-constrained environments. In many developing countries, including Nigeria, In some developing-country secondary school contexts, including Nigeria, mathematics instruction can be constrained by large class sizes, limited teaching materials and technological resources, and curricular or time pressures that reduce opportunities for student-centred or differentiated learning (Am et al., 2023; Fufa et al., 2023; Osei et al., 2025; Pham et al., 2025). These conditions reduce the likelihood that teachers can adopt innovative, student-centred approaches or provide targeted support based on students' learning trajectories.

Another critical dimension is the cognitive difficulty inherent in learning algebra. Students often struggle to form new mental models for interpreting variables, expressions, and functional relationships. These struggles are not simply individual deficits but are symptomatic of widespread systemic issues, such as inadequate instructional scaffolding and a lack of metacognitive support (Gnawali, 2024; Subedi, 2020). In many cases, students' misunderstandings persist because instruction fails to address the underlying conceptual gaps and instead focuses on rule-based solutions. The misalignment between intended curricula and actual classroom practice further compounds these issues. Even where reform-oriented policies advocate for conceptually rich and inquiry-based learning, their implementation is frequently inconsistent. Teachers may revert to traditional methods due to limited training, time constraints, or pressure to cover

syllabus content for high-stakes assessments (Prendergast & Treacy, 2018). These mismatches not only dilute the effectiveness of curricular reforms but also perpetuate teaching practices that are disconnected from how students best learn algebra.

Addressing these multifaceted challenges requires a pedagogical shift toward more responsive and reflective teaching. Research underscores the potential of integrating technology, such as dynamic algebra environments and intelligent tutoring systems, to support student engagement and personalised learning pathways (Córdova-Esparza & Jimenez Piñon, 2025). Equally important is equipping teachers with the professional knowledge to interpret students' thinking and adapt instruction accordingly. Walkoe (2015) emphasises that professional development focused on understanding students' reasoning processes can help teachers move beyond procedural instruction to foster deeper conceptual understanding. Overcoming the persistent challenges in algebra education necessitates a holistic approach. Solutions must address not only cognitive and pedagogical dimensions but also contextual realities such as class size, infrastructure, and teacher capacity. This calls for a sustained investment in instructional innovation, curriculum alignment, and teacher professional development, all grounded in an understanding of how students learn algebra most effectively.

2.3. Advanced Organisers as a Cognitive Instructional Strategy

Advance organisers have gained prominence as effective cognitive instructional tools designed to support learners in integrating new information with existing knowledge structures. Grounded in Ausubel's theory of meaningful learning, advance organisers function not as simple overviews but as high-level conceptual frameworks that help learners navigate new content more effectively. By providing cognitive scaffolds before instruction begins, they reduce dependence on rote memorisation and promote deeper understanding and retention (Arora & Kaur, 2024). Their capacity to activate prior knowledge and structure the learning process makes them especially relevant in subjects that require abstract reasoning, such as mathematics and science. Recent empirical studies affirm the value of advance organisers in enhancing various dimensions of academic performance. Tools such as concept maps, graphical representations, and mind maps have been shown to improve learners' problem-solving skills, analytical thinking, and ability to manage complex information (Arora & Kaur, 2024; Gulzar, 2025; Gunawan et al., 2020). These benefits are evident across diverse educational contexts and subject areas, including mathematics, language arts, and the sciences (Mufidah, 2024; Teng, 2022). In mathematics education specifically, where abstract concepts often pose cognitive challenges, advance organisers offer a structured approach that supports comprehension and promotes meaningful engagement with content. The effectiveness of advance organisers extends beyond traditional face-to-face classrooms. In blended and technology-enhanced learning environments, such as flipped classrooms or online learning platforms, organisers help learners process and retain material more efficiently by reducing cognitive overload (Elfeky et al., 2020). These tools serve to streamline learners' focus, clarify expectations, and promote active engagement with course materials. The ability to visually organise and interconnect concepts becomes particularly valuable when dealing with complex mathematical tasks that require both procedural fluency and conceptual understanding.

Moreover, graphical and visual forms of advance organisers, such as mind maps and flowcharts, have shown particular promise. Studies suggest that these formats can outperform more text-heavy or linear organisers in fostering student comprehension, especially for learners with visual or holistic cognitive styles (Mufidah, 2024). Interestingly, their effectiveness appears consistent across gender, suggesting that advance organisers can serve as inclusive instructional strategies that accommodate diverse learning preferences (Aslan, & Arabacı, 2023).

Beyond academic performance, the use of advanced organisers contributes to broader cognitive and affective outcomes. Learners exposed to these strategies tend to exhibit increased curiosity, improved metacognitive awareness, and more precise reasoning (Gulzar, 2025; Patel & Trivedi, 2020). This holistic impact underscores their potential to cultivate not only content mastery but also essential 21st-century skills such as critical thinking, independent learning, and intellectual autonomy. Despite their proven effectiveness, the application of advanced organisers in specific mathematical domains, such as algebra, remains underexplored, particularly in low-resource educational settings. While several studies have demonstrated their general utility, there is a paucity of research on how advanced organisers can be systematically integrated into algebra instruction to address known cognitive and pedagogical challenges. Furthermore, the interaction between advanced organisers and other learner variables, such as interest, engagement, or self-efficacy in mathematics, remains an area requiring deeper investigation. This gap highlights the need for contextually grounded studies that explore the use of advance organisers as part of

comprehensive teaching strategies in mathematics education. Such research could offer insights into how these tools might be tailored to meet the cognitive demands of algebra and support equitable learning outcomes across diverse student populations.

2.4. Empirical Evidence on the Use of AOs in Mathematics

The efficacy of advance organisers [AOs] as pedagogical tools is widely supported by empirical research across various disciplines and educational levels. Grounded in cognitive learning theory, AOs are typically introduced before instruction and serve as structured aids that help learners organise and relate new knowledge to what they already know. Numerous studies have shown that this pre-instructional strategy enhances comprehension, long-term retention, and overall academic performance by facilitating meaningful learning and reducing cognitive overload (Elfeky et al., 2020; Gunawan et al., 2020; Majeed, 2021).

In mathematics education, the use of AOs has been particularly impactful in improving students' problem-solving abilities and conceptual understanding. Empirical studies, including experimental and quasi-experimental designs, consistently demonstrate that students taught using AOs perform significantly better than those exposed to conventional teaching methods. These improvements are evident in key areas such as integrated science process skills, mathematics achievement scores, and logical reasoning abilities (Gunawan et al., 2020; Majeed, 2021). For instance, the structured use of graphical organisers in algebra and geometry lessons has been found to scaffold students' understanding of complex relationships, enhance their ability to generalise mathematical principles, and increase engagement in problem-solving activities (Elfeky et al., 2020). Beyond mathematics, the benefits of AOs extend to language learning and science education. In language classrooms, for example, pre-listening and pre-reading organisers such as brainstorming sessions and visual summaries have improved comprehension, boosted learner confidence, and reduced performance anxiety (Li et al., 2019; Long, 2023). These findings suggest that AOs can serve dual cognitive and affective functions by structuring knowledge acquisition while also fostering a more relaxed and engaging learning environment. Such outcomes have also been documented in science education, where AOs support inquiry-based learning and promote integrated reasoning skills (Gunawan et al., 2020).

Importantly, the integration of AOs in digital and blended learning contexts has received growing attention. In flipped classrooms and online learning environments, AOs such as video summaries, interactive mind maps, and guided notes have proven effective in improving students' preparation, understanding, and interaction with instructional content (Elfeky et al., 2020). These applications are particularly beneficial for complex topics, where learners must manage multiple concepts simultaneously and require cognitive support before formal instruction begins. Synthesis of findings from various empirical reviews confirms the broad applicability and pedagogical value of AOs. Studies have emphasised that these strategies not only improve measurable academic outcomes but also nurture curiosity, independent thinking, and deeper inquiry-based learning habits (Arora & Kaur, 2024; Patel & Trivedi, 2020). Their flexibility in adapting to different subjects, age groups, and instructional settings, ranging from traditional classrooms to e-learning platforms, reinforces their relevance in modern educational practice.

Despite these promising results, there remains a limited body of research specifically examining the use of AOs in secondary school mathematics within under-resourced or developing country contexts. Most existing studies have been conducted in relatively well-supported environments, leaving a gap in understanding how AOs function in settings characterised by overcrowded classrooms, curriculum rigidity, or limited access to instructional technology. Moreover, few studies have investigated how AOs interact with learner-specific variables such as interest, engagement, and mathematical self-efficacy, factors critical to sustained achievement in mathematics. Addressing this gap requires rigorous, context-sensitive research that explores not only the effectiveness of AOs in diverse learning environments but also their capacity to serve as inclusive tools that respond to individual differences and pedagogical challenges in mathematics education. Such studies could inform policy and practice by providing empirically grounded strategies for enhancing mathematics instruction in varied educational settings.

2.5. Gender and Mathematics Performance

The relationship between gender and mathematics performance has been the subject of extensive empirical investigation, yielding a complex and often contested body of evidence. Large-scale international assessments, such as TIMSS and PISA, generally report negligible overall gender differences in mathematics achievement across countries. However, the nature and magnitude of these differences are shaped by contextual variables including the specific country, cultural setting, student age, and the type of assessment used (Cantley & McAllister, 2021; Hyde, 2016; Reilly et al., 2019). These findings support the gender

similarities hypothesis, which posits that males and females perform comparably on most cognitive tasks, including mathematics.

Nonetheless, more granular analyses reveal that the observed gender parity in mathematics can mask subtle disparities. For example, some studies indicate that when reading ability is statistically controlled, particularly in standardised assessments that involve complex word problems, boys often outperform girls, suggesting that test design may inadvertently obscure underlying performance differences (Lu et al., 2023). Additionally, gender gaps are not uniform across educational stages or global regions. In some non-OECD countries and at certain levels of schooling, girls have been found to outperform boys in mathematics, challenging the traditional narrative of male advantage (Arroyo-Barrigüete et al., 2023; Li et al., 2018; Reilly et al., 2019).

Psychological and sociocultural factors further complicate the gender-performance dynamic. Math anxiety has been consistently shown to affect girls more than boys, potentially dampening performance and engagement, even when actual competence is comparable (Rodríguez et al., 2020; Vos et al., 2023). Meanwhile, boys tend to exhibit greater confidence in their mathematical abilities, often overestimating their performance, which can influence their willingness to pursue math-intensive academic and career paths (Bench et al., 2015). These motivational factors operate in tandem with gender stereotypes, which may discourage girls from developing positive attitudes toward mathematics, particularly in environments where math is implicitly framed as a male domain.

A recurring observation in the literature is the wider variability in boys' mathematical performance. Studies have found that boys are overrepresented at both the highest and lowest ends of the achievement spectrum, whereas girls' performance tends to be more concentrated around the mean (Li et al., 2018; Reilly et al., 2019). This variability contributes to the greater male representation in mathematically elite groups, but also to a higher proportion of boys struggling with basic competencies, highlighting the need for differentiated instructional support. Contextual influences, including socioeconomic status, school type, geographic location, and national levels of gender equality, further shape gender patterns in mathematics achievement. Interestingly, higher national gender equity does not always correlate with reduced gender gaps in performance, suggesting that local cultural attitudes and educational practices exert a stronger influence than broad policy frameworks (Bench et al., 2015; Brown & Alexandersen, 2020; Li et al., 2018). In rural or under-resourced settings, both boys and girls may face structural barriers to learning, but these challenges can affect genders differently depending on prevailing societal norms.

While gender-based differences in mathematics performance do exist, they are generally small, context-dependent, and mediated by an intricate interplay of cognitive, affective, and sociocultural factors (Cantley & McAllister, 2021; Hyde, 2016; Reilly et al., 2019). A nuanced understanding of these dynamics is crucial for developing equitable instructional strategies and for avoiding simplistic generalisations that reinforce existing stereotypes. Future research should continue to explore how gender intersects with other learner characteristics, such as motivation, interest, and self-efficacy, particularly within specific cultural contexts and subject domains like algebra, where gendered patterns may be more or less pronounced.

2.6. Advance Organisers and Gender Equity

Gender equity in mathematics education continues to be a critical concern globally, despite substantial progress in improving access and participation for both male and female students. Persistent disparities remain in performance, engagement, and representation, particularly at the highest levels of mathematical achievement, where boys often outnumber girls in many countries (Meinck & Brese, 2019; Zhu et al., 2018). At the same time, girls are sometimes underrepresented at both extremes of the achievement spectrum, reflecting broader structural and sociocultural influences. These inequities are shaped not only by school-level factors but also by national-level indicators such as labour market gender equality, cultural norms, and expectations surrounding gender roles (Chua, 2024; Gevrek et al., 2020). Emerging research highlights the importance of classroom-based strategies that actively support gender equity in mathematics learning. Among these, the use of advance organisers offers considerable promise. Advance organisers can scaffold learning in ways that reduce cognitive overload, clarify complex concepts, and promote metacognitive awareness, benefits that are particularly valuable for students who may face psychological barriers such as math anxiety, which disproportionately affects girls (Elfeky et al., 2020; Rodríguez et al., 2020). By helping learners activate and structure prior knowledge, these tools can level the cognitive playing field, especially when paired with inclusive instructional strategies such as cooperative learning and differentiated instruction (Prieto-Saborit et al., 2021).

Moreover, advance organisers contribute to creating inclusive learning environments by supporting diverse cognitive styles and reducing reliance on prior experience with formal mathematics. This flexibility makes them well-suited to bridging gender-related gaps in conceptual understanding, problem-solving, and self-confidence. In doing so, they challenge implicit stereotypes that portray mathematics as a male-dominated discipline and affirm the capabilities of all learners, regardless of gender (Chua, 2024; Leder, 2019). The strategic use of concept maps, mind maps, and other graphical organisers can be particularly empowering for female students, enabling them to visually organise abstract content and take ownership of their learning processes (Gulzar, 2025; Mufidah, 2024).

However, achieving gender-equitable outcomes in mathematics education requires more than simply introducing advanced organisers or other pedagogical tools. It demands an intentional focus on the quality of learning experiences and a commitment to addressing the broader contextual factors that perpetuate inequity. This includes dismantling gendered expectations in classroom discourse, curricula, and assessment practices, and ensuring that instructional approaches are designed with sensitivity to the varied needs of male and female learners (Leder, 2019; Nimely & Ogw, 2023). Teachers play a pivotal role in this process, yet evidence suggests that many preservice and in-service educators lack sufficient awareness of how gender dynamics manifest in mathematics classrooms (Mewborn & Gober, 2024). Professional development that enhances teacher understanding of gender-sensitive pedagogy is therefore essential.

Advance organisers represent a valuable pedagogical tool in the pursuit of gender equity in mathematics education. When thoughtfully implemented within inclusive and reflective instructional frameworks, they can enhance learning outcomes for all students while narrowing gender-based disparities. Nonetheless, their effectiveness depends on systemic support, teacher intentionality, and a sustained commitment to transforming classroom practices and cultural assumptions that hinder equitable participation in mathematics (Gevrek et al., 2020; Leder, 2019).

In summary, research has consistently demonstrated that Ausubel's Advance Organizers can promote meaningful learning by improving comprehension, retention, and integration of new concepts across a variety of subjects. This body of work represents settled knowledge confirming the instructional value of AOs. However, two important gaps remain. First, there is limited empirical evidence on the systematic application of AOs in algebra instruction, a domain where students frequently encounter persistent difficulties. Second, while gender-related differences in mathematics performance have been widely debated, the moderating influence of gender in the effectiveness of AOs has not been conclusively established. Addressing these gaps provides the theoretical and practical basis for the present study.

2.7. Identified Gaps in the Literature

A critical synthesis of the literature on algebra instruction, the use of Advance Organizers, and gender in mathematics education reveals several significant gaps that warrant scholarly attention. Although algebra occupies a central place in the secondary mathematics curriculum and serves as a gateway to higher-order mathematical reasoning (Imasuen & Stanley, 2022; Prendergast & Treacy, 2018), many students continue to struggle with its abstract concepts and symbolic representations. This persistent underachievement suggests that prevailing instructional approaches may be inadequate for fostering the deep conceptual understanding necessary for success in algebra, particularly in resource-constrained contexts.

First, while the positive impact of AOs on academic achievement has been documented across disciplines, including science and general mathematics (Elfeky et al., 2020; Gunawan et al., 2020), there remains limited empirical research on their systematic application to algebra specifically. Algebraic content is uniquely abstract and cognitively demanding, requiring strategies that effectively bridge prior knowledge with new symbolic structures. Moreover, little is known about the relative effectiveness of different forms of AOs (e.g., graphic, narrative, or conceptual organizers) on algebraic performance.

Second, although gender disparities in mathematics performance have been widely studied, findings are often inconclusive and context-dependent (Cantley & McAllister, 2021; Reilly et al., 2019). Few studies have employed experimental or quasi-experimental designs to investigate how instructional strategies such as AOs interact with gender to influence learning outcomes. In particular, the role of AOs in promoting gender equity beyond achievement scores by shaping engagement, self-efficacy, or conceptual mastery remains underexplored.

Third, most prior studies on AOs have been conducted in technologically advanced educational environments. There is a paucity of research on their effectiveness in traditional, face-to-face classrooms in sub-Saharan Africa, where infrastructural limitations and pedagogical challenges are pronounced.

Contextually grounded studies are therefore needed to examine the feasibility, adaptability, and impact of AOs in under-resourced classroom settings.

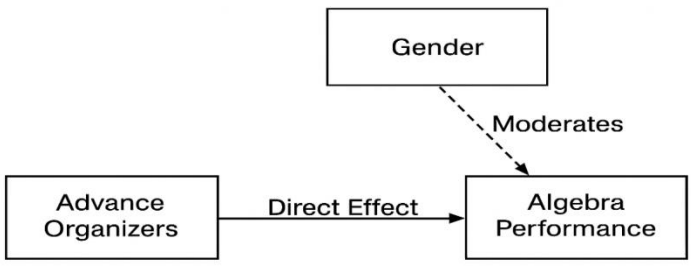
Finally, while theoretical literature advocates for integrated and conceptually rich methods of teaching algebra (Botuzova & Nichyshyna, 2023; Kaput, 2017), few empirical studies have validated these recommendations through robust experimental research. The mediating role of AOs in supporting conceptual change, long-term retention, and transfer of learning remains under-investigated, as does the sustainability of AO-based interventions over time.

This study seeks to address these gaps by focusing specifically on the use of AOs to improve algebra performance among senior secondary school students in Nigeria. It further examines the moderating role of gender in students' responses to AO-based instruction, employing a quasi-experimental design to generate empirical evidence on both effectiveness and equity. In doing so, it contributes to the global discourse on context-sensitive instructional strategies and offers practical insights for enhancing mathematics education in low-resource settings.

3. Theoretical Framework

This study utilizes Ausubel's Subsumption Theory of Meaningful Learning as its foundational theoretical framework to investigate the effects of advance organizers on students' performance in algebra. Ausubel's theory offers a coherent perspective on the cognitive processes involved in acquiring abstract mathematical knowledge and suggests ways to enhance this learning. Specifically, the theory advocates that well-designed and sequenced instructional interventions can promote more meaningful learning compared to rote memorization or unstructured teaching methods. As a result, this framework informs the development of research objectives, the formulation of hypotheses, instructional design, and the interpretation of outcomes, ensuring alignment between theory and methodology. According to Ausubel, meaningful learning occurs when new information is connected to relevant prior knowledge already present in the learner's cognitive structure. He emphasized that instruction should aim to foster this type of learning by introducing advance organizers, preparatory materials provided before the lesson. These organizers serve to activate prior knowledge and set up a conceptual scaffold for assimilating new, complex information. In the context of algebra, which is often viewed as abstract and cognitively challenging, using advance organizers can help students relate new algebraic principles to previously learned arithmetic or real-life situations. This connection supports improved comprehension, better retention, and more effective problem-solving. Within the framework of this study, advance organizers are treated as the independent variable, while algebra performance is the dependent variable. The instructional strategy is operationalized through the structured use of concept-based or narrative advance organizers designed to precede each algebra lesson. Additionally, the study introduces gender as a moderating variable to examine potential differences in the effectiveness of the instructional strategy between male and female students. This inclusion is based on prior research highlighting gender-related variations in mathematics achievement and engagement. Although Ausubel's Subsumption Theory primarily focuses on cognitive processes, its application through advance organizers has significant implications for equity in mathematics education. By providing structured scaffolds that make complex algebraic concepts more accessible, advance organizers may help reduce barriers often faced by underrepresented groups, including female students. Thus, the framework not only supports meaningful learning for all learners but also provides a theoretical basis for investigating whether gender moderates the effectiveness of advance organizer-based instruction. The relationships among these variables are conceptually illustrated in Figure 1, which depicts the theoretical framework guiding this research.

Figure 1
Conceptual Framework Based on Ausubel's Subsumption Theory of Meaningful Learning



As shown in the Figure 1, the use of advanced organisers (instructional strategy) is hypothesised to have a direct positive effect on students' algebra performance. Gender is modelled as a moderating variable that may influence the strength or direction of this relationship.

The application of Ausubel's theory in this study is justified by its demonstrated effectiveness in explaining how learners integrate new information meaningfully when instruction is carefully designed. Several recent empirical studies (Githua & Nyabwa, 2008; Jamil et al., 2025) affirm the value of advance organisers in enhancing mathematical understanding, especially in topics such as algebra that require abstract reasoning. Despite these strengths, the theory does present certain limitations. Its emphasis is primarily cognitive, and it may not fully account for affective or motivational variables such as interest or self-efficacy, which also influence learning. Nevertheless, its cognitive orientation aligns well with the present study's focus on improving students' academic performance in mathematics. Finally, Ausubel's framework complements the quasi-experimental research design employed in this study. It not only informs the development of instructional interventions but also supports the use of Analysis of Covariance for evaluating the treatment effects, given its concern with controlling for prior knowledge. This alignment ensures that both instructional and analytical procedures are theoretically grounded, thereby enhancing the validity and reliability of the research findings.

4. Methodology

4.1. Research Design

The study adopted a quasi-experimental design using a pretest–posttest control group structure with a gender-based comparison. This design was chosen to examine the causal effect of Ausubel's Advance Organizers on students' algebra performance while exploring whether gender moderated the effect. The use of intact classes preserved natural classroom dynamics and reduced disruption to regular school schedules, thereby enhancing the ecological validity of the study. Random assignment of individual participants was not possible due to administrative and ethical considerations; however, schools with similar demographic characteristics were selected to ensure comparability between treatment groups.

4.2. Participants

The population comprised all Senior Secondary Two (SS2) students in public secondary schools within Zaria Metropolis, Kaduna State, Nigeria. According to official enrollment records, there were 3,532 students (1,663 males and 1,869 females) across ten schools, including boys-only, girls-only, and coeducational institutions. From this population, two coeducational public secondary schools with comparable teacher quality and resource conditions were purposively selected. Intact SS2 classes from these schools were then assigned to the experimental and control groups through simple random sampling.

A total of 164 students participated in the study, comprising 83 students in the experimental group and 81 in the control group. Both schools had nearly balanced gender representation, allowing for meaningful gender-based analysis. SS2 students were specifically chosen because algebra is a core component of their curriculum, and they possess sufficient cognitive maturity to engage with meaningful learning strategies.

4.3. Data Collection Instruments

The main instrument for data collection was the Algebra Performance Test [APT], developed by the researcher to measure students' conceptual understanding, procedural fluency, and problem-solving skills in algebra. The test consisted of 50 multiple-choice questions based on SS2 algebra content from the Nigerian secondary school mathematics curriculum. Each correct response was awarded two marks, giving a maximum possible score of 100.

To ensure content validity, the APT was reviewed by three experts in Mathematics Education and Educational Measurement and Evaluation. Their feedback guided the revision of items to ensure clarity, alignment with curriculum objectives, and cognitive appropriateness. The instrument was pilot-tested on 30 SS2 students from a non-participating school to determine reliability. Using a test–retest method, the Pearson Product-Moment Correlation Coefficient was .85, indicating high reliability and internal consistency.

4.4. Procedure

The intervention lasted six weeks, with three 80-minute sessions per week. To ensure instructional consistency, both the experimental and control groups were taught by the researcher, while two trained mathematics teachers monitored classroom fidelity and assisted with logistics. In the experimental group, students were taught algebra using Ausubel's Advance Organizer strategy, following the model of Stone,

Weil, and Calhoun. The instruction was organized into three phases. In the preparatory phase, students were introduced to the lesson objectives and provided with concept maps or analogies to activate prior knowledge. In the presentation phase, new algebraic concepts were introduced hierarchically through guided questioning, examples, and structured visual aids. In the integration phase, learners summarized key ideas, engaged in peer teaching, and reflected on the connections between prior and new knowledge to strengthen understanding. In contrast, the control group received conventional lecture-based instruction, which emphasized teacher explanation, textbook examples, and individual exercises, with limited interaction or discovery. The pretest was administered one week before the intervention, while the posttest was conducted one week after the final session. The same items were used in both assessments, but their order was rearranged to reduce recall bias. Each test lasted 90 minutes and was administered under standardized conditions.

4.5. Data Analysis

Quantitative data were analyzed using IBM SPSS Version 27. Descriptive statistics (mean, standard deviation) were computed to summarize students' performance by group and gender. Inferential analysis was performed using Analysis of Covariance [ANCOVA] to determine the effect of the instructional method on posttest performance, controlling for pretest scores. This approach helped account for baseline differences and provided a more accurate estimate of the instructional effect. Effect sizes were also calculated to assess the magnitude of differences between the experimental and control groups. All analyses were conducted at a .05 level of significance.

4.6. Ethical Procedures

Ethical clearance for the study was obtained from the Kaduna State Ministry of Education and relevant school authorities. Informed consent was secured from school administrators, teachers, and student participants. Participation was voluntary, and all responses were treated with confidentiality and anonymity. No potential risks were associated with participation, and data were used solely for academic purposes in accordance with accepted ethical guidelines for educational research.

5. Results

This section presents the results of the study based on the research questions and hypotheses formulated. Descriptive statistics were used to address the research questions, while inferential statistics tested the null hypotheses at a .05 level of significance using SPSS Version 27. The findings provide empirical evidence on the effectiveness of Ausubel's Advance Organisers on students' performance in algebra and their differential impact across gender.

5.1. Difference in Mean Performance Scores of Experimental and Control Groups

Descriptive statistics were computed for both the experimental group (taught using Ausubel's Advance Organizers) and the control group (taught using the conventional lecture method). Table 1 presents the mean and standard deviation scores for both groups in the pretest and posttest.

Table 1
Descriptive Statistics of Students' Performance in Algebra by Instructional Group

Group	*N*	*Pretest Mean*	*SD*	*Posttest Mean*	*SD*	*Mean Difference*
Experimental	83	44.69	9.80	70.49	11.20	25.80
Control	81	46.44	9.98	50.90	10.19	4.46

Table 1 displays the mean pretest and posttest scores for the experimental and control groups. The experimental group (n = 83), taught using Ausubel's Advance Organisers, recorded a posttest mean of 70.49 (*SD* = 11.20) and a pretest mean of 44.69 (*SD* = 9.80). The control group (*n* = 81), taught using the conventional lecture method, had a posttest mean of 50.90 (*SD* = 10.19) and a pretest mean of 46.44 (*SD* = 9.98). The figure shows a marked improvement in the experimental group's posttest performance, while pretest scores remained comparable across groups, indicating similar initial abilities.

In this study, the first null hypothesis tested stated that there is no significant difference between the mean performance scores of students taught algebra using Ausubel's Advance Organizers and those taught using the lecture method. To test this hypothesis, an independent samples t-test was conducted at the 0.05 level of significance. The results of this analysis are presented in Table 2.

Table 2
Independent Samples t-Test Results on Performance of Students in Experimental and Control Groups

Groups	*N*	*Mean*	*S.D.*	*M.D.*	*t(df)*	*p*	*95% CI*	*Cohen's d*
Experimental	83	70.49	11.2	19.58	t (162) = 11.71	< .001	[16.28, 22.89]	1.83
Control	81	50.90	10.19					

The results in Table 2 indicate a statistically significant difference in the post-test performance scores of students between the experimental and control groups. An independent samples *t*-test was conducted to determine the effect of Ausubel's Advance Organisers on students' performance in algebra compared to the conventional lecture method. The Levene's test for equality of variances was not significant, F (1, 162) = 0.83, p = .365, indicating that the assumption of homogeneity of variances was met. Therefore, the row for "equal variances assumed" was used for interpreting the *t*-test results. The analysis revealed that students who received instruction through Ausubel's Advance Organisers (M = 70.49, SD = 11.20, n = 83) outperformed those taught with the lecture method (M = 50.90, SD = 10.19, n = 81). The mean difference between the two groups was 19.58, and this difference was found to be statistically significant, t (162) = 11.71, p < .001. The 95% confidence interval for the mean difference ranged from 16.28 to 22.89, confirming that the difference is not only statistically significant but also unlikely to have occurred by chance.

In addition to statistical significance, the magnitude of the observed effect was assessed using multiple effect size estimates. Cohen's d was calculated to be 1.83, which falls within the "very large" range according to the guidelines by Cohen (2013), indicating a strong practical impact of the intervention. To further validate this finding, Hedges' g, which adjusts for sample size bias, was also computed and yielded a value of 1.82, very close to Cohen's d, thereby reinforcing the robustness of the effect. Furthermore, Glass's Δ, which uses only the standard deviation of the control group to estimate effect size, was found to be 1.92. This measure is particularly appropriate in educational experiments where the intervention might have affected not just the mean but also the variability of scores. The slightly higher value of Glass's Δ suggests that the observed gains in the experimental group are even more pronounced when compared directly to the variability within the untreated control group. Together, these inferential statistics indicate both a statistically and practically significant effect of Ausubel's Advance Organisers on students' mathematics performance. The convergence of large effect sizes across Cohen's d, Hedges' g, and Glass's Δ confirms the educational importance of the instructional method. Therefore, the null hypothesis stating that there is no significant difference in performance between students taught with Ausubel's Advanced Organisers and those taught with the lecture method is rejected. The evidence supports the conclusion that Ausubel's Advance Organisers significantly improve algebra achievement among senior secondary school students.

5.2. Gender Differences in the Experimental Group

Descriptive statistics of posttest scores for male and female students in the experimental group are presented in Table 3.

Table 3
Descriptive Statistics on the performance of Male and Female students in the Experimental Group

Group	*N*	*Mean*	*SD*	*Mean Difference*
Male	40	69.30	12.53	−2.33
Female	43	71.59	9.81	

Table 3 displays the descriptive statistics of posttest performance scores by gender among students in the experimental group. A total of 83 students participated in this stage of the study, consisting of 40 male and 43 female students. The average posttest score for male students was 69.28 (SD = 12.53), indicating a moderate range of performance around the mean. In comparison, female students recorded a slightly higher mean score of 71.61 (SD = 9.81), suggesting their scores were more consistently close to the group average. When considering the entire experimental group, the overall mean posttest score was 70.49 with a standard deviation of 11.20. These results show that both male and female students achieved relatively high scores following the instructional intervention. The smaller standard deviation among female students indicates less variation in their performance compared to their male counterparts. This descriptive overview offers insight into how students performed after the instructional treatment, providing a useful basis for understanding general patterns of achievement by gender within the experimental group. It contributes to addressing the research questions by summarising observed trends in student outcomes.

In this study, the second null hypothesis tested stated that there is no significant difference in the performance of male and female students taught algebra using Ausubel's Advance Organizers. To test this hypothesis, an ANCOVA was conducted, with pretest scores treated as the covariate. The dependent variable was posttest performance in algebra, while gender (male and female) served as the independent variable. The results of this analysis are presented in Table 4.

Table 4
ANCOVA Summary Table for Gender Difference in Posttest Performance (Controlling for Pretest Scores)

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*p*	*Partial Eta Squared*
Corrected Model	119.919[a]	2	59.960	.472	.625	.012
Intercept	17899.810	1	17899.810	140.984	<.001	.638
Pretest	7.327	1	7.327	.058	.811	.001
Gender_Num	108.078	1	108.078	.851	.359	.011
Error	10157.039	80	126.963			
Total	422661.368	83				
Corrected Total	10276.958	82				

The results in Table 4 show that there is no statistically significant difference in the posttest performance scores of male and female students exposed to Ausubel's Advance Organizers. An Analysis of Covariance was conducted to determine whether gender had a significant effect on students' algebra performance after controlling for pretest scores. The ANCOVA revealed that the covariate (pretest) was not a significant predictor of posttest scores, $F(1, 80) = 0.058$, $p = .811$, indicating minimal influence of students' prior knowledge on the outcome. More importantly, the main effect of gender was not statistically significant, $F(1, 80) = 0.851$, $p = .359$. This suggests that male ($M = 69.30$, $SE = 1.78$) and female ($M = 71.59$, $SE = 1.72$) students performed similarly in algebra after the intervention. The 95% confidence interval for the adjusted mean difference between male and female students ranged from −7.23 to 2.65, encompassing zero, further reinforcing the lack of statistically meaningful difference. The partial eta squared value ($\eta^2_p = .011$) indicated a very small effect size, implying that gender accounted for just about 1.1% of the variance in posttest performance scores. Therefore, the null hypothesis stating that there is no significant difference in the performance of male and female students taught algebra using Ausubel's Advanced Organizers is retained. These findings suggest that the instructional strategy is equally effective for both genders, promoting equitable learning outcomes in mathematics regardless of gender identity.

6. Discussion

This study investigated the effect of Ausubel's Advance Organizers on senior secondary school students' performance in algebra and examined whether gender moderated the effectiveness of the strategy. Grounded in Ausubel's Subsumption Theory of Meaningful Learning, the study sought to determine whether providing structured conceptual frameworks before instruction could promote deeper understanding and equitable learning outcomes in an under-resourced Nigerian context.

The findings demonstrated that students taught with Ausubel's Advance Organizers outperformed those taught using the conventional lecture method. This result affirms the central premise of meaningful learning theory that new knowledge is best acquired when it is anchored to relevant prior knowledge. The use of AOs helped students build conceptual bridges between their existing cognitive structures and the abstract algebraic content, resulting in more meaningful engagement and better comprehension. These findings corroborate previous studies that reported significant improvements in student achievement through the use of AOs and other cognitively scaffolded instructional models (Elfeky et al., 2020; Gunawan et al., 2020; Guo et al., 2023). The evidence suggests that the integration of conceptual organizers encourages learners to actively structure and internalize new information, thereby reducing rote memorization and promoting long-term retention.

Importantly, this study extends Ausubel's theoretical propositions to the context of sub-Saharan African classrooms, where limited resources and teacher-centred pedagogies often constrain effective mathematics instruction. By demonstrating that AOs can yield meaningful learning outcomes in traditional classroom settings without dependence on technological enhancements, the study provides practical evidence of the strategy's adaptability and scalability. Similar conclusions have been reached in recent cross-cultural studies emphasizing that cognitive scaffolding remains effective across diverse educational contexts (Ishak et al.,

2025; Ramaila, 2025). Such findings reinforce the universality of Ausubel's theory as a robust foundation for instructional innovation in mathematics.

The study further revealed that both male and female students benefited equally from AO-based instruction. This suggests that when instructional approaches are cognitively inclusive, gender ceases to be a determinant of achievement in mathematics. The result aligns with the growing body of international literature indicating that gender gaps in mathematics are largely contextual, influenced by factors such as classroom climate, societal expectations, and self-efficacy rather than innate cognitive differences (Hyde, 2016; Rodríguez et al., 2020; Vos et al., 2023). By emphasizing conceptual understanding over procedural repetition, AOs appear to offer equitable entry points for learners regardless of gender. This finding resonates with recent empirical work by Mufidah (2024), who reported that cognitive-based pedagogies help neutralize performance disparities by providing structured learning experiences that accommodate diverse cognitive styles.

Interpreted through Ausubel's framework, the success of the AO approach can be attributed to its ability to organize and activate relevant prior knowledge before the introduction of new material. This process reduces cognitive overload and enhances schema formation, enabling learners to make meaningful connections within algebraic structures. By presenting advance conceptual maps and analogical examples, AOs guided students to perceive relationships among algebraic concepts rather than treating them as isolated procedures. Such scaffolding likely promoted metacognitive reflection and encouraged independent problem-solving critical skills for mathematical proficiency.

The equitable outcomes observed in this study also highlight the inclusive potential of AOs. Since the strategy emphasizes cognitive readiness over affective or social factors, it provides a learning environment where both male and female students can succeed equally. This reinforces the argument that pedagogical quality, rather than student demographics, exerts the strongest influence on mathematics achievement. Recent reviews of mathematics education research support this claim, underscoring that effective instruction characterized by conceptual scaffolding and learner engagement can significantly reduce performance gaps associated with gender, socio-economic status, or cultural background (Faella et al., 2025; Zhu et al., 2023).

Overall, the findings contribute to a broader international conversation on promoting meaningful and equitable mathematics learning. They underscore the value of low-cost, theory-driven instructional approaches that can be effectively implemented in resource-constrained environments. By aligning theoretical insight, empirical evidence, and classroom practice, this study advances the discourse on cognitive equity and provides actionable guidance for educators and policymakers. Future research should extend this work by exploring the longitudinal and affective impacts of AO-based instruction, particularly in areas such as students' motivation, self-efficacy, and problem-solving persistence. Integrating qualitative data, such as classroom observations or learner interviews, would further enrich understanding of how cognitive scaffolding translates into sustained learning engagement.

In conclusion, this study affirms the pedagogical and theoretical validity of Ausubel's Advance Organizers in enhancing students' algebra performance and promoting gender-equitable learning outcomes. It highlights that meaningful learning when carefully structured and cognitively grounded has the power to transform mathematics instruction, even in contexts facing systemic educational challenges.

7. Conclusion and Recommendations

With the results of this study, it would be overly simplistic to claim that Advance Organizers alone can resolve the persistent challenges associated with algebra instruction among senior secondary school students. Rather, the findings of this research should be viewed as a foundational step in elevating the role of structured, cognitively grounded instructional strategies, particularly Ausubel's Advance Organizers, in transforming how algebra is taught and learned in under-resourced educational settings such as Nigeria. The evidence suggests that AOs do not merely enhance academic performance in algebra; they also hold promise as equitable tools that support both male and female students. This alone is significant. Yet the impact of AOs extends beyond test scores: they reduce abstraction, activate prior knowledge, and foster conceptual connections. Such processes may help students engage more meaningfully with mathematical content and develop greater confidence in their learning. We believe this shift in perspective towards deeper, more intentional instructional design has the potential to improve mathematics teaching and learning, particularly in topics like algebra that often elicit anxiety, confusion, and disengagement. Teachers in Nigeria and similar contexts continue to work under considerable constraints. By offering strategies like AOs that are low-cost, scalable, and theoretically grounded, we provide them with practical tools to better support diverse learners and promote inclusive pedagogy. Future studies should build on this work by examining

the longitudinal effects of AOs on learning retention and conceptual transfer. Equally important is the investigation of how AOs influence students' attitudes, motivation, and self-efficacy affective variables that play a critical role in shaping mathematics outcomes, particularly in gendered learning environments. In addition, researchers may consider adapting AOs to other challenging areas of the mathematics curriculum, such as geometry or calculus, and evaluating their impact across different cultural and educational contexts.

8. Limitations

Several limitations of the present study should be acknowledged. First, treatment conditions were assigned at the school level rather than randomized across individual students, which may have introduced school-level confounds. Second, although efforts were made to standardize lesson delivery, the possibility of instructor-related effects cannot be completely ruled out. Third, the study relied exclusively on quantitative test data; the absence of qualitative data, such as classroom observations or student interviews, limited our ability to capture the processes underlying the observed learning gains. Fourth, the study sample was purposively drawn from only two schools within Zaria Metropolis, thereby limiting the generalizability of the findings to broader contexts. Future research should therefore employ multi-site randomized designs, incorporate multiple instructors to control for teacher effects, and adopt mixed-methods approaches that combine performance outcomes with qualitative insights into student learning.

Despite these limitations, this research contributes meaningfully to the growing conversation on cognitive equity in mathematics education. It challenges us to think critically about how we design learning environments and to ask whether our instructional strategies are truly serving all learners. The results advocate for the broader integration of AOs into mathematics pedagogy and invite educators, researchers, and policymakers to reconsider how algebra and by extension, mathematics, can be taught in ways that are both effective and inclusive. Ultimately, the work presented here is not a conclusion but an invitation: to deepen our understanding of how students learn, to question traditional pedagogies, and to imagine new possibilities for mathematics instruction that is rigorous, responsive, and empowering.

Author contributions: Gladys Matthew Ezumezuh conceptualized the study, developed the research design, and contributed to the literature review and manuscript drafting. Chibueze Eze supervised the study, reviewed the methodology, and provided critical revisions to the manuscript. Kazaik Benjamin Danlami handled data collection, data analysis, interpretation of results, and contributed to manuscript writing and editing. All authors read and approved the final manuscript.

Funding: The authors declare that no external funding was received for this study.

Declaration of interest: The authors declare that there is no conflict of interest regarding the publication of this article.

Data availability: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical statement: Ethical approval was obtained from the relevant institutional review board prior to data collection. Informed consent was obtained from all participants, and participation was voluntary. Confidentiality and anonymity of respondents were strictly maintained in accordance with standard research ethics.

References

Altunışık, S., Uzun, S., & İnel Ekici, D. (2023). The effect of problem-based STEM practices on pre-service science teachers' conceptual understanding. *Journal of Pedagogical Research, 7*(5), 344-358. https://doi.org/10.33902/JPR.202323628

Am, M. A., Hadi, S., Istiyono, E., & Retnawati, H. (2023). Does differentiated instruction affect learning outcome? Systematic review and meta-analysis. *Journal of Pedagogical Research, 7*(5), 18–33. https://doi.org/10.33902/JPR.202322021

Arora, S., & Kaur, A. (2024). A Review: Advance organizer model – an efficient model of teaching and learning. *Shodh Sari-An International Multidisciplinary Journal*, *03*(02), 219–226. https://doi.org/10.59231/SARI7698

Arroyo-Barrigüete, J. L., Carabias-López, S., Borrás-Pala, F., & Martín-Antón, G. (2023). Gender differences in mathematics achievement: the case of a business school in Spain. *Sage Open*, *13*(2), 21582440231166922. https://doi.org/10.1177/21582440231166922

Arthur, Y. D., Owusu, E. K., Asiedu-Addo, S., & Arhin, A. K. (2018). Connecting mathematics to real life problems: A teaching quality that improves students' mathematics interest. *IOSR Journal of Research & Method in Education*, *8*(4), 65–71.

Aslan, A., & Arabacı, D. (2023). *The use of Thinglink Web 2.0 tool in out-of-school learning environments in mathematics teaching: Pre-service teachers' experiences. Journal of Pedagogical Sociology and Psychology, 5*(3), 263–282. https://doi.org/10.33902/jpsp.202323919

Ausubel, D. P. (1960). *The use of advance organizers in the learning and retention of meaningful verbal material. Journal of Educational Psychology, 51*, 267–272. https://doi.org/10.1037/h0046669

Awofala, A. O. A., & Lawani, A. O. (2020). *Increasing mathematics achievement of senior secondary school students through differentiated instruction. Journal of Educational Sciences,* 4(1), 1–19. https://doi.org/10.31258/jes.4.1.p.1-19

Bench, S. W., Lench, H. C., Liew, J., Miner, K., & Flores, S. A. (2015). Gender gaps in overestimation of math performance. *Sex Roles*, *72*(11–12), 536–546. https://doi.org/10.1007/s11199-015-0486-9

Booth, J. L., Oyer, M. H., Paré-Blagoev, E. J., Elliot, A. J., Barbieri, C., Augustine, A., & Koedinger, K. R. (2015). Learning algebra by example in real-world classrooms. *Journal of Research on Educational Effectiveness*, *8*(4), 530–551.

Botuzova, Y., & Nichyshyna, V. (2023). Intra-subject integration in secondary school mathematics teaching (on the example of integration of algebraic and geometric problem solving methods). *Academic Notes Series Pedagogical Science*, *210,* 14-21. https://doi.org/10.36550/2415-7988-2023-1-210-14-21

Bozkuş, F., Kalaycı, Ö., & Toluk Uçar, Z. (2025). An analysis of algebra lesson: Can apples and pears be added? *Journal of Pedagogical Research, 9*(1), 274–295. https://doi.org/10.33902/JPR.202529564

Brown, G. R., & Alexandersen, K. (2020). Gender equality and gender gaps in mathematics performance. *Trends in Cognitive Sciences*, *24*(8), 591–593. https://doi.org/10.1016/j.tics.2020.06.002

Cantley, I., & McAllister, J. (2021). The gender similarities hypothesis: insights from a multilevel analysis of high-stakes examination results in mathematics. *Sex Roles*, *85*(7–8), 481–496. https://doi.org/10.1007/s11199-021-01234-5

Chua, V. C. G. (2024). Engendering gendered mathematics education in the Philippines: Is equality to access enough? *Power and Education*, *16*(2), 139–149. https://doi.org/10.1177/17577438231174132

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge.

Córdova-Esparza, D.-M., & Jimenez Piñon, A. (2025). Analysis of teaching strategies and learning challenges in linear algebra. *CLEI Electronic Journal*, *28*(2), 11. https://doi.org/10.19153/cleiej.28.2.11

Dereje, E. W. (2023). The effect of inquiry based technology integration on conceptual and procedural geometry knowledge of preservice mathematics teachers. *Journal of Pedagogical Sociology and Psychology, 5*(4), 12-27. https://doi.org/10.33902/jpsp.202321592

Elfeky, A. I. M., Masadeh, T. S. Y., & Elbyaly, M. Y. H. (2020). Advance organizers in flipped classroom via e-learning management system and the promotion of integrated science process skills. *Thinking Skills and Creativity*, *35*, 100622. https://doi.org/10.1016/j.tsc.2019.100622

Faella, P., Digennaro, S., & Iannaccone, A. (2025). Educational practices in motion: A scoping review of embodied learning approaches in school. *Frontiers in Education*, *10*, 1568744. https://doi.org/10.3389/feduc.2025.1568744

Fufa, F. S., Tulu, A. H., & Ensene, K. A. (2023). Examining the challenges of using student-centred teaching strategies in secondary schools: A qualitative approach. *Journal of Pedagogical Sociology and Psychology, 5*(3), 61–72. https://doi.org/10.33902/jpsp.202323181

Gevrek, Z. E., Gevrek, D., & Neumeier, C. (2020). Explaining the gender gaps in mathematics achievement and attitudes: The role of societal gender equality. *Economics of Education Review*, *76*, 101978. https://doi.org/10.1016/j.econedurev.2020.101978

Githua, B. N., & Nyabwa, R. A. (2008). Effects of advance organiser strategy during instruction on secondary school students' mathematics achievement in Kenya's Nakuru district. *International Journal of Science and Mathematics Education*, *6*(3), 439–457. https://doi.org/10.1007/s10763-006-9037-8

Gnawali, Y. P. (2024). Difficulties in studying abstract algebra at the undergraduate level. *Pragyaratna प्रज्ञारत्न*, *6*(1), 110–122. https://doi.org/10.3126/pragyaratna.v6i1.64542

Gulzar, S. (2025). Graphical advance organizers and their impact to develop higher order thinking skills among secondary science school students. *Inverge Journal of Social Sciences*, *4*(2), 42–51. https://doi.org/10.63544/ijss.v4i2.124

Guo, J., Tang, X., Marsh, H. W., Parker, P., Basarkod, G., Sahdra, B., Ranta, M., & Salmela-Aro, K. (2023). The roles of social–emotional skills in students' academic and life success: A multi-informant and multicohort perspective. *Journal of Personality and Social Psychology, 124*(5), 1079–1110. https://doi.org/10.1037/pspp0000426

Gunawan, G., Harjono, A., Nisyah, M., Kusdiastuti, M., & Herayanti, L. (2020). Improving students' problem-solving skills using inquiry learning model combined with advance organizer. *International Journal of Instruction*, *13*(4), 427–442. https://doi.org/10.29333/iji.2020.13427a

Henríquez-Rivas, C., & Verdugo-Hernández, P. (2024). Teachers' mathematical work based on examples presented in the teaching of algebra in secondary education. *Frontiers in Education*, *9*, 1346091. https://doi.org/10.3389/feduc.2024.1346091

Herscovics, N. (2018). Cognitive obstacles encountered in the learning of algebra. In S. Wagner & C. Kieran (Eds.), *Research Issues in the Learning and Teaching of Algebra* (1st ed., pp. 60–86). Routledge. https://doi.org/10.4324/9781315044378-6

Hyde, J. S. (2016). Sex and cognition: Gender and cognitive functions. *Current Opinion in Neurobiology*, *38*, 53–56. https://doi.org/10.1016/j.conb.2016.02.007

Imasuen, K., & Stanley, O. E. (2022). Proficiency in algebraic equations as a predictor of secondary school students' academic achievement in mathematics. *African Journal of Mathematics and Statistics Studies*, *5*(3), 33–42. https://doi.org/10.52589/AJMSS-3MYQULVV

Ishak, M., Oderinde, I., & Ahmad, S. (2025). The role of metacognitive strategies in enhancing learning outcomes and educational efficiency: A systematic review of quantitative, qualitative and mixed-method studies. *International Journal of Academic Research in Business and Social Sciences*, *15*(4), 81–101.

Jamil, N., Rosli, R., & Mahmud, M. S. (2025). Algebraic trends impact school mathematics education: A bibliometric review. *Multidisciplinary Reviews*, *8*(9), 2025261–2025261.

Kaput, J. J. (2017). 1 What is algebra? What is algebraic reasoning? In J. J. Kaput, D. W. Carraher, & M. L. Blanton (Eds.), *Algebra in the early grades* (1st ed., pp. 5–18). Routledge. https://doi.org/10.4324/9781315097435-2

Leder, G. C. (2019). Gender and mathematics education: An overview. In G. Kaiser & N. Presmeg (Eds.), *Compendium for early career researchers in mathematics education* (pp. 289–308). Springer. https://doi.org/10.1007/978-3-030-15636-7_13

Li, C.-H., Wu, M.-H., & Lin, W.-L. (2019). The use of a "Think-pair-share" brainstorming advance organizer to prepare learners to listen in the l2 classroom. *International Journal of Listening*, *33*(2), 114–127. https://doi.org/10.1080/10904018.2017.1394193

Li, M., Zhang, Y., Liu, H., & Hao, Y. (2018). Gender differences in mathematics achievement in Beijing: A meta-analysis. *British Journal of Educational Psychology*, *88*(4), 566–583. https://doi.org/10.1111/bjep.12203

Long, Y. (2023). How to use advance organizer in reading. *Frontiers in Sustainable Development*, *3*(7), 73–76. https://doi.org/10.54691/fsd.v3i7.5334

Lu, Y., Zhang, X., & Zhou, X. (2023). Assessing gender difference in mathematics achievement. *School Psychology International*, *44*(5), 553–567. https://doi.org/10.1177/01430343221149689

Majeed, S. S. A. (2021). Effects of advance organizer teaching model on students academic performance in mathematics in secondary school. *International Journal of Creative Research Thoughts (IJCRT)*, *9*(3), 971–976.

Meinck, S., & Brese, F. (2019). Trends in gender gaps: Using 20 years of evidence from TIMSS. *Large-Scale Assessments in Education*, *7*(1), 8. https://doi.org/10.1186/s40536-019-0076-3

Mewborn, D. S., & Gober, D. A. (2024). Preservice teachers' perceptions of gender equity issues in the mathematics classroom. *NOMAD Nordic Studies in Mathematics Education*, *6*(1), 146499. https://doi.org/10.7146/nomad.v6i1.146499

Moralı, H. S., & Filiz, A. (2023). Incorrect theorems and proofs: An analysis of pre-service mathematics teachers' proof evaluation skills. *Journal of Pedagogical Research, 7*(3), 248–262. https://doi.org/10.33902/JPR.202318840

Mufidah, L.-L. N. (2024). Effectiveness of advanced organizer learning strategies on the achievement of fiqh with varied cognitive styles. *Al-Hayat: Journal of Islamic Education*, *8*(1), 305. https://doi.org/10.35723/ajie.v8i1.502

Mpuangnan, K. N., Adjei, B. K., & Govender, S. N. (2024). Impact of multiple representations-based instruction on teaching and learning of linear equations. *Journal of Pedagogical Sociology and Psychology, 6*(1), 58–76. https://doi.org/10.33902/jpsp.202425242

Nigerian Educational Research and Development Council. (2012). *Senior secondary education curriculum: Mathematics for SS1–3.* NERDC Press.

Nimely, D. R., & Ogw, F. N., K. (2023). Strategies for inculcating gender equity in mathematics classrooms for enhancement of learners' problem-solving skills. *International Journal of Research and Innovation in Social Science*, *7*(7), 1446–1454. https://doi.org/10.47772/IJRISS.2023.70814

Niringiyimana, E., & Maniraho, J. F. (2023). The impact of algebra background on upper secondary students' performance in mathematics: a case of study of Ruhango District. *Journal of Research Innovation and Implications in Education*, 270–286. https://doi.org/10.59765/nfir1835

Osei, E. G., Boakye, R. O., & Osei-Bona, H. K. (2025). Video-based multimedia instructions and academic performance: An analysis of gender differences in learning linear equations at the basic school. *Sustainable and Pedagogical Technologies, 1*(1), e41090. https://doi.org/10.33902/SPT.202541090

Patel, M., & Trivedi, D. (2020). Advance organizer model: reviews of past studies. *Research Guru: Online Journal of Multidisciplinary Subjects*, *14*(1), 25–28.

Pham, H. T. H., Pham, Q. D., Bui, C. K., & Le, H. T. (2025). Factors affecting the effectiveness of math teachers' integrated teaching in secondary schools: The case of Vietnam. *Journal of Pedagogical Research, 9*(1), 235–253. https://doi.org/10.33902/JPR.202532448

Prendergast, M., & Treacy, P. (2018). Curriculum reform in Irish secondary schools – a focus on algebra. *Journal of Curriculum Studies*, *50*(1), 126–143. https://doi.org/10.1080/00220272.2017.1313315

Prieto-Saborit, J. A., Méndez-Alonso, D., Cecchini, J. A., Fernández-Viciana, A., & Bahamonde-Nava, J. R. (2021). Cooperative learning for a more sustainable education: gender equity in the learning of maths. *Sustainability*, *13*(15), 8220. https://doi.org/10.3390/su13158220

Ramaila, S. (2025). Cognitively guided instruction in education: A review of research trends and classroom applications. *Cogent Education*, *12*(1), 2550619. https://doi.org/10.1080/2331186X.2025.2550619

Reilly, D., Neumann, D. L., & Andrews, G. (2019). Investigating gender differences in mathematics and science: results from the 2011 trends in mathematics and science survey. *Research in Science Education*, *49*(1), 25–50. https://doi.org/10.1007/s11165-017-9630-6

Rodríguez, S., Regueiro, B., Piñeiro, I., Estévez, I., & Valle, A. (2020). Gender differences in mathematics motivation: differential effects on performance in primary education. *Frontiers in Psychology*, *10*, 3050. https://doi.org/10.3389/fpsyg.2019.03050

Sansyzbayeva, A., Daiyrbekov, S., Berdaliyev, D., Daiyrbekova, G., & Sansyzbayev, A. (2024). Methods of teaching secondary school students to solve algebraic equations and inequalities and their systems. *Scientific Herald of Uzhhorod University Series Physics*, *56*, 1464–1473. https://doi.org/10.54919/physics/56.2024.146vf4

Shamash, J. (2019). From equations to structures: linking abstract algebra and high-school algebra for secondary school teachers. In A. Rogerson & J. Morska (Eds.), *Theory and practice: an interface or a great divide?* (1st Edition, pp. 517–522). WTM-Verlag Münster. https://doi.org/10.37626/GA9783959871129.0.97

Subedi, A. (2020). Experiencing students' difficulties in learning abstract algebra. *Tribhuvan University Journal*, *35*(1), 57–67. https://doi.org/10.3126/tuj.v35i1.35871

Suominen, A. L. (2018). Abstract algebra and secondary school mathematics connections as discussed by mathematicians and mathematics educators. In N. H. Wasserman (Ed.), *Connecting abstract algebra to secondary mathematics, for secondary mathematics teachers* (pp. 149–173). Springer. https://doi.org/10.1007/978-3-319-99214-3_8

Tarfa, F. S., & Dike, C. O. (2022). *Gender differences in the academic performance of students in senior secondary school mathematics. International Journal of Innovative Science and Research Technology, 7*(3), 424–430. https://www.ijisrt.com/assets/upload/files/IJISRT22MAR389_%281%29.pdf

Teng, F. (2022). Vocabulary learning through videos: Captions, advance-organizer strategy, and their combination. *Computer Assisted Language Learning*, *35*(3), 518–550. https://doi.org/10.1080/09588221.2020.1720253

Tshering, K., Dorji, P., & Jatsho, S. (2024). Enhancing students' behavioural and cognitive engagement through active learning strategies in physics. *International Journal of Didactical Studies, 5*(1), 23328. https://doi.org/10.33902/ijods.202423328

Veith, J. M., Bitzenbauer, P., & Girnat, B. (2022). Towards describing student learning of abstract algebra: insights into learners' cognitive processes from an acceptance survey. *Mathematics*, *10*(7), 1138. https://doi.org/10.3390/math10071138

Vlach, H. A., & Sandhofer, C. M. (2011). Developmental differences in children's context-dependent word learning. *Journal of Experimental Child Psychology*, *108*(2), 394–401.

Vos, H., Marinova, M., De Léon, S. C., Sasanguie, D., & Reynvoet, B. (2023). Gender differences in young adults' mathematical performance: Examining the contribution of working memory, math anxiety and gender-related stereotypes. *Learning and Individual Differences*, *102*, 102255. https://doi.org/10.1016/j.lindif.2022.102255

Walkoe, J. (2015). Exploring teacher noticing of student algebraic thinking in a video club. *Journal of Mathematics Teacher Education*, *18*(6), 523–550. https://doi.org/10.1007/s10857-014-9289-0

Wangmo, R., Giri, N., Ghalley, L. R., Jamtsho, Y., & Zangmo, T. (2025). Using of claim, evidence, and reasoning strategy in scientific explanation and argumentative writing skills of grade nine chemistry students. *Journal of Pedagogical Sociology and Psychology, 7*(4), 19-43. https://doi.org/10.33902/jpsp.202533548

Warren, E., Trigueros, M., & Ursini, S. (2016). Research on the learning and teaching of algebra. In Á. Gutiérrez, G. C. Leder, & P. Boero (Eds.), *The second handbook of research on the psychology of mathematics education* (pp. 73–108). Sense Publishers. https://doi.org/10.1007/978-94-6300-561-6_3

Zhu, C., Leung, C. O.-Y., Lagoudaki, E., Velho, M., Segura-Caballero, N., Jolles, D., Duffy, G., Maresch, G., Pagkratidou, M., & Klapwijk, R. (2023). Fostering spatial ability development in and for authentic STEM learning. *Frontiers in Education*, *8*, 1138607. https://doi.org/10.3389/feduc.2023.1138607

Zhu, Y., Kaiser, G., & Cai, J. (2018). Gender equity in mathematical achievement: The case of China. *Educational Studies in Mathematics*, *99*(3), 245–260. https://doi.org/10.1007/s10649-018-9846-z