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Research Article

Bridging Mathematics Achievement Gaps: An Intersectional Analysis of Vulnerable Student Populations in U.S. Schools

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ABSTRACT

Persistent inequalities in mathematics achievement continue to represent one of the most persistent forms of educational inequality worldwide. Despite decades of policy reforms aimed at improving inclusive education, students with disabilities, economically disadvantaged students and English learners continue to perform below the general student population in mathematics assessments. These disparities limit not only academic success but also long-term access to higher education, STEM careers and socioeconomic mobility. This study examines variations in mathematics achievement gaps among students with disabilities, economically disadvantaged students and English learners during the 2021-2022 academic year. Using large-scale state-level assessment data, the study applies comparative statistical analysis, including analysis of variance (ANOVA), grade-level trend evaluation and regression modeling, to examine demographic disparities and intersectional effects across educational stages. The analysis captures both between-state differences and within-grade performance patterns to provide a system-level understanding of achievement inequality. The findings reveal substantial and statistically significant disparities across demographic groups and states. Achievement gaps widen progressively as students advance through grade levels, with the most pronounced declines occurring during middle and higher grade levels. Students experiencing intersecting disadvantages, particularly disability combined with economic hardship or language barriers, demonstrate consistently lower mathematics proficiency outcomes when compared with students facing a single challenge. Results further indicate that variations in educational resources, instructional support systems and inclusive teaching practices contribute significantly to observed performance differences. This study concludes that closing mathematics achievement gaps requires investments in inclusive education, targeted instructional support and policies designed to ensure that every student has a fair opportunity to succeed. Therefore, the study recommends that Governments at both federal and state levels should therefore prioritize funding models that direct additional resources to schools and regions where achievement gaps are most pronounced.

Keywords: Mathematics Achievement, Educational Inequality, Inclusive Education, Intersectionality, Learning Disparities; Equity in Education

1. INTRODUCTION

Mathematics is widely regarded as one of the most essential subjects in education because it develops students' capacity for logical reasoning, analytical thinking and problem-solving (McKnight & Morgan, 2020; Yang & Wang, 2025). These competencies are not only fundamental for academic success but are also increasingly important in economies driven by science, technology, engineering and innovation. A strong foundation in mathematics enables students to pursue higher education, enter competitive careers and actively participate in knowledge-based societies (Osborne & Hibbard, 2025; Meng, 2025; Razak et al., 2025).

Despite its importance, mathematics achievement remains unevenly distributed across student populations. Persistent disparities continue to exist between the general student population and historically underserved groups, particularly students with disabilities (Gifford & Hull, 2016; Perelmutter et al., 2017; Fernández-Batanero et al., 2022; Johnson et al., 2025), economically disadvantaged students (Chiu, 2015; Balang, 2026; Nwoye et al., 2026), and English learners (Smith, 2016; Stubbs, 2016; Anggoro et al. 2025; Armah et al. 2025). Evidence from large-scale educational research shows that these groups consistently record lower performance on standardized mathematics assessments compared with their peers. These disparities are not simply academic statistics; they reflect deeper structural issues related to access to resources, instructional support and learning environments. For instance, research by Ming Chiu (2015) demonstrates that both school-level and family-level inequalities significantly influence students' mathematics outcomes. Similarly, Osborne and Hibbard (2025) show that school climate, resource availability, and student attitudes toward mathematics play important roles in shaping achievement patterns across different demographic groups.

Students with disabilities often require specialized instructional strategies, adaptive technologies, and individualized learning support to fully engage with mathematics instruction. However, many schools struggle to provide consistent support due to limited resources or insufficient teacher preparation (Perelmutter et al., 2017; Fernández-Batanero et al., 2022). Economically disadvantaged students face another set of challenges. Schools serving low-income communities frequently operate with fewer instructional materials, larger class sizes, and limited access to enrichment opportunities such as tutoring or advanced coursework (Chiu, 2015; Nwoye et al., 2026). English learners must simultaneously develop language proficiency while learning complex mathematical concepts, which can slow their progress when language support is limited (Stubbs, 2016; Anggoro et al. 2025).

These realities highlight an important principle in education: equal access to resources does not always translate into equal outcomes (Rasheed et al. 2025). When education systems provide identical support to all students without recognizing differences in learning needs and socioeconomic circumstances, achievement gaps tend to persist or even widen. Over time, these disparities may reinforce broader social and economic inequalities (NCES, 2020; Zeeshan, 2024).

Mathematics proficiency also has long-term implications for students' life opportunities. Individuals with strong quantitative skills are more likely to pursue careers in science, technology, engineering, and related fields, which are among the fastest-growing sectors in modern economies (Arici et al., 2019; Alkhasawneh, 2025). Conversely, students who struggle with mathematics early in their academic journey may avoid advanced coursework or STEM-related career paths (Meng, 2025). For example, a student with a learning disability who lacks adequate instructional support may fall behind in foundational concepts, limiting future academic choices (Fernández-Batanero et al., 2022). Similarly, students from low-income households may have limited access to tutoring, learning technologies, or enrichment programs that could strengthen their mathematical understanding (Nwoye et al., 2026). English learners may possess strong reasoning abilities but face difficulty interpreting complex word problems written in unfamiliar language structures (Anggoro et al. 2025).

Because of these long-term consequences, reducing mathematics achievement gaps has become both an educational priority and a broader societal concern. Education systems across many countries have introduced reforms designed to improve equity in learning outcomes (Zeeshan, 2024; Miftachurohmah et al., 2025). Policies have included targeted funding, accountability measures and programs aimed at supporting disadvantaged learners (Juandi et al., 2025). However, despite these efforts, significant disparities remain.

One reason for the persistence of these gaps is that many existing studies examine disadvantaged student groups in isolation. Research often focuses separately on disability status (Gifford & Hull, 2016; Perelmutter et al., 2017; Fernández-Batanero et al., 2022; Johnson et al., 2025), socioeconomic disadvantage (Chiu, 2015; Balang, 2026; Nwoye et al., 2026), or language proficiency (Smith, 2016; Stubbs, 2016; Anggoro et al. 2025; Armah et al. 2025). While these studies provide valuable insights, they do not fully capture how these factors interact within real educational environments. Students frequently experience multiple forms of disadvantage simultaneously, and these overlapping conditions may produce more complex patterns of achievement inequality.

Recent research has also highlighted the potential of technology-supported learning environments to address some of these challenges. For example, Rosenberg and Pit-ten Cate (2018), Cui et al. (2019), Meng (2025) emphasize the growing role of adaptive technologies and artificial intelligence in supporting inclusive education. Their work

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suggests that personalized learning systems can help address diverse student needs by adjusting instructional pace, simplifying complex material, and providing targeted feedback. Likewise, initiatives supported by the Bill & Melinda Gates Foundation (2015) highlight the promise of personalized learning models in improving outcomes for disadvantaged students. While these developments are encouraging, much of the existing literature focuses on specific interventions rather than examining large-scale patterns of achievement gaps across multiple student groups (Perelmutter et al., 2017).

This study addresses these gaps by analyzing mathematics achievement among students with disabilities, economically disadvantaged students and English learners during the 2021-2022 academic year using state-level data. By analyzing patterns across demographic groups, grade levels and state contexts, this study aims to identify where achievement gaps are most pronounced and how overlapping forms of disadvantage shape these patterns. Without this broader perspective, it becomes difficult to identify where inequalities are most severe or how they evolve as students progress through school.

Understanding these patterns is essential for designing policies and interventions that address the root causes of achievement disparities rather than only their symptoms. Ultimately, identifying where and why these achievement gaps occur is a necessary step toward building a more inclusive education system. A clearer understanding of these disparities can help educators design more responsive instructional strategies, guide policymakers in allocating resources more effectively, and support schools in creating learning environments where all students have a genuine opportunity to succeed in mathematics.

2. LITERATURE REVIEW

In recent years, educational research has paid increasing attention to differences in mathematics achievement among student groups. Scholars and policymakers have become particularly concerned about students who historically face greater challenges within the education system, including students with disabilities, economically disadvantaged students, and English learners. Studies consistently show that these groups often perform below the general student population in mathematics. These differences are not simply academic issues; they are closely tied to broader social and economic inequalities within society. Reports from organizations such as the National Center for Education Statistics highlight how gaps in educational outcomes reflect differences in access to resources, instructional support, and learning opportunities (NCES, 2020).

One important theme in the literature is the role of personalized learning and targeted support systems (Pane et al., 2017; Saarinen et al., 2018; Lobczowski & Cohen, 2021). Many researchers argue that traditional one-size-fits-all instruction does not adequately serve students who face additional learning barriers. Instead, tailored learning approaches, often supported by technology, can help address individual needs more effectively. For example, research has shown that assistive technologies such as speech-to-text systems, visual learning tools and interactive platforms can significantly improve learning experiences for students with disabilities.

Adaptive learning technologies represent another important development in this area. These systems adjust instruction based on how a student is progressing, offering additional explanations, practice problems or feedback when needed. Studies suggest that such tools can be particularly helpful for students who may have gaps in foundational mathematics knowledge. In many cases, adaptive platforms provide the type of individualized attention that teachers may struggle to provide in large classrooms. This makes them especially valuable for students from disadvantaged backgrounds who may not have access to tutoring or academic support outside of school. In this way, technology-supported personalized learning aligns closely with the principles of equitable education by ensuring that support is distributed according to students' needs rather than applied uniformly (McKnight & Morgan, 2020).

Another major theme in the literature concerns the influence of socioeconomic status on mathematics achievement. Students from lower-income households often face challenges that extend beyond the classroom. Limited access to learning materials, unstable learning environments, and reduced academic support at home can all influence academic outcomes. Studies such as Perelmutter et al. (2017), Lobczowski and Cohen (2021), Fernández-Batanero et al. (2022) have shown that when schools implement targeted support programs, such as personalized learning initiatives or additional academic assistance, students from economically disadvantaged backgrounds often

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experience measurable improvements in achievement. These findings suggest that academic gaps are not inevitable; rather, they can be reduced when education systems actively respond to differences in students' circumstances.

Language barriers also play a significant role in shaping mathematics outcomes. For English learners, difficulty understanding the language used in textbooks, exams, or classroom explanations can make mathematics appear more complex than it actually is. Mathematics often involves specialized vocabulary and word-based problem solving, which means language proficiency can influence how well students interpret questions and instructions. Studies examining technology-supported instruction show that digital learning tools and artificial intelligence-based platforms can help address these challenges by simplifying language, providing visual explanations, and offering interactive feedback.

The literature further suggests that age and grade level can influence how students respond to educational interventions. Younger students often adapt quickly to digital tools and interactive learning platforms because these technologies align with their everyday experiences. Early exposure to supportive learning environments can therefore play an important role in strengthening foundational mathematics skills. At the same time, older students may face increasing academic pressure as mathematical concepts become more complex (Rosenberg & Pit-ten Cate, 2018). If gaps in understanding are not addressed early, they may widen over time. This highlights the importance of early and sustained interventions designed to support diverse learners as they progress through the education system.

Theoretical Framework

Understanding differences in mathematics achievement requires more than simply comparing test scores. It also requires a clear explanation of *why* certain groups of students may experience advantages or disadvantages within the education system. To guide this study, two complementary perspectives are used: Social Equity Theory and Constructivist Learning Theory. Together, these frameworks help explain how unequal access to resources and differences in learning support can shape students' academic outcomes.

The first guiding perspective is Social Equity Theory. At its core, this theory argues that fairness in education does not mean treating every student in exactly the same way. Instead, fairness means ensuring that each student has access to the support and resources they need to succeed. Students do not enter classrooms with identical circumstances. Some may face economic hardship, some may have learning disabilities, and others may still be developing proficiency in the language used for instruction. When these differences are ignored, educational systems can unintentionally reinforce inequality rather than reduce it.

From the perspective of social equity, students with disabilities may require assistive technologies, specialized instruction, or additional time to fully engage with mathematical concepts. Economically disadvantaged students may benefit from academic support programs, stable learning environments, and access to learning materials that may not be readily available at home.

English learners may need language scaffolding, vocabulary support, or bilingual instruction to properly interpret mathematical problems and explanations. Social Equity Theory therefore encourages education systems to move beyond uniform policies and toward approaches that recognize and respond to these differences.

In relation to the present study, Social Equity Theory helps explain why mathematics achievement gaps may appear between demographic groups. If resources, instructional support, or learning opportunities are distributed unevenly, certain students may face greater obstacles in developing mathematical skills. Examining differences in achievement across these groups therefore provides insight into whether educational structures are adequately supporting students who face additional challenges. In this way, the theory provides a lens for interpreting achievement gaps as signals of where additional support or policy attention may be needed.

The second framework guiding this research is Constructivist Learning Theory. Constructivism emphasizes that learning is not simply the passive absorption of information. Instead, students actively build new knowledge based on their prior experiences, understanding, and interactions within the classroom. Influential scholars such as Jean

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Piaget and Lev Vygotsky emphasized that learning occurs through engagement, problem solving, social interaction, and the gradual construction of understanding.

Within mathematics education, constructivist thinking highlights the importance of teaching methods that connect new material with what students already know. Students learn more effectively when instruction is responsive to their developmental level, language abilities, and cognitive needs. This perspective suggests that a single uniform teaching approach may not be equally effective for all students. Some students may require visual aids, step-by-step scaffolding, collaborative learning opportunities, or adaptive technologies in order to fully grasp mathematical ideas.

This framework is particularly relevant when examining students with disabilities, economically disadvantaged students, and English learners. For students with disabilities, adaptive learning tools and differentiated instruction may help them engage with mathematical concepts more effectively. English learners may benefit from simplified language, visual explanations, and opportunities to discuss mathematical reasoning. Economically disadvantaged students may need additional foundational support if earlier learning opportunities were limited. Constructivist theory therefore highlights how differences in learning conditions can translate into differences in academic outcomes.

Applied to this study, Constructivist Learning Theory suggests that achievement gaps may emerge when instructional approaches do not adequately reflect the diverse ways students learn. If teaching methods, classroom resources, or support systems fail to align with students' needs, some groups of students may struggle to build the knowledge required for success in mathematics. By examining performance patterns across groups, the study provides insight into whether current educational environments are supporting meaningful learning for all students.

Review of Related Studies

A careful reading of earlier studies shows that many scholars now see technology as a promising way to support students who struggle academically, especially in mathematics. One important example is the meta-analysis conducted by Gifford and Hull in 2016. Their study brought together findings from several investigations on assistive technologies used in education. The strength of their work lies in the broad overview it provides, showing that technological tools can help improve learning outcomes for many students. However, the studies included in their analysis used different research designs, contexts, and sample sizes. Because of this variation, the findings cannot always be generalized to every learning environment. In practice, the effectiveness of assistive technology often depends on how it is implemented and the specific needs of the students involved.

In a similar direction, Cui et al. (2019) and McKnight and Morgan (2020) examined adaptive learning technologies and their role in supporting mathematics achievement. Their study provides strong evidence that adaptive digital tools can personalize learning and help students progress at their own pace. Despite these contributions, the authors also point out an important limitation. Technology alone does not automatically improve academic performance. Factors such as teacher training, instructional quality, and access to relevant learning materials remain critical. When teachers are not adequately prepared to use technological tools, the benefits of these innovations may be reduced.

Another influential contribution is the literature review by Rosenberg and Pit-ten Cate (2018), which explored the role of artificial intelligence in special education. Their work highlights the potential of AI to support inclusive learning environments by tailoring instruction to students' individual needs. However, because their study relied mainly on previously published literature rather than new empirical data, it offers limited evidence on the direct effect of AI on measurable learning outcomes. Likewise, reports from the National Center for Education Statistics (2020) provide valuable descriptive statistics on educational performance gaps. While these reports clearly document disparities among students, they do not fully explain the underlying causes of these gaps or identify specific solutions.

One of the earliest large-scale international investigations into educational inequality was carried out by Ming Chiu (2015) using data from the Programme for International Student Assessment, conducted by the Organisation for Economic Co-operation and Development. Analysing data from hundreds of thousands of students across many countries, the study found that both family inequality and school inequality significantly reduce mathematics

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achievement. The research also showed that these forms of inequality operate through different mechanisms, including teacher availability, educational resources, and socioeconomic background. The findings emphasize the importance of equitable distribution of educational resources if academic performance is to improve globally.

More recent empirical studies further support the role of technology in enhancing mathematics learning. For instance, Nteziryimana and Niyobuhungiro (2023) examined the integration of ICT in public secondary schools in Rwanda. Using a correlational research design involving both teachers and students, they found that students exposed to ICT-supported instruction performed significantly better than those taught without technological tools. In a related study, Nishimwe and Mugiraneza (2023) also reported strong positive relationships between technology use and students' mathematical competence. Their findings show that the use of computers and specialized mathematics software improves both student engagement and academic performance.

Further evidence comes from more recent studies conducted in other regions. For example, Miftachurohmah et al. (2025) found a significant positive relationship between ICT-supported instruction and students' mathematics achievement in Indonesian secondary schools. Similarly, Alkhasawneh (2025) demonstrated that AI-supported mobile learning platforms significantly improve students' mathematics scores and motivation compared with traditional teaching methods. These findings reinforce the growing consensus that digital technologies can make learning more engaging and effective when used appropriately.

Beyond the use of technology, researchers have also explored innovative teaching strategies that can help reduce achievement gaps in mathematics. Zeeshan (2024) highlighted several effective approaches, including culturally responsive teaching, peer-assisted learning, project-based learning, and technology-supported instruction. These strategies were found to increase student participation, strengthen conceptual understanding, and improve problem-solving abilities, particularly among students from underserved communities. Supporting this view, Juandi and colleagues (2025) conducted a meta-analysis showing that computer-assisted mathematics learning combined with project-based instruction produces strong improvements in students' academic outcomes.

Another important stream of research focuses on psychological and motivational influences on students' academic performance. Razak and colleagues (2025) found that intrinsic motivation plays a crucial role in students' success in mathematics and science subjects, particularly among students from disadvantaged backgrounds. Likewise, Yang and Wang (2025) showed that parents' educational aspirations positively influence students' mathematics achievement by strengthening students' confidence and beliefs about their ability to succeed. Supporting these findings, Nwoye and colleagues (2026) reported that mathematics self-esteem improves academic performance, while test anxiety negatively affects students' achievement.

Teacher characteristics and school environments have also been identified as important determinants of mathematics outcomes. For instance, Armah and colleagues (2025) found that teacher professional development, student motivation, and a strong academic culture were stronger predictors of mathematics achievement than socioeconomic background. Similarly, Osborne and Hibbard (2025), using data from international education assessments, observed that students' attitudes toward mathematics significantly influence their achievement levels.

More recently, scholars have begun examining the role of artificial intelligence in reducing educational inequality. For example, Rasheed and colleagues (2025) found that AI-driven personalized learning systems improve student engagement and learning outcomes. However, they also noted important concerns such as data privacy, ethical use of algorithms, and the risk of technological bias. In a similar discussion, Yingyou Meng (2025) argued that AI-supported learning systems enhance motivation and academic performance by providing adaptive feedback and personalized learning pathways.

Other studies show that mathematics achievement is also shaped by broader structural inequalities. Chiphambo (2025) found that gender differences in mathematics performance are influenced by self-efficacy, classroom interactions, and social expectations. Likewise, Balang (2026) reported that rural-urban achievement gaps are driven by unequal access to technology, weaker foundational learning, and limited family support. In sum, the reviewed studies show that improving mathematics achievement requires a multidimensional approach. Technology

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integration, effective teaching practices, student motivation and supportive school environments all interact to shape learning outcomes.

3. METHODOLOGY

This study adopts a quantitative, cross-sectional research design to examine differences in mathematics achievement among key student populations during the 2021–2022 academic year. The purpose of the design is to provide a clear snapshot of how mathematics performance varies across different groups of students within the same time period. By relying on standardized educational data collected across states, the study is able to make consistent comparisons between students with disabilities, economically disadvantaged students and English learners. A quantitative approach is appropriate because it allows the study to measure differences objectively and test whether those differences are statistically meaningful.

The analysis relies on publicly available statewide education data contained in the dataset **SY2122_FS175_DG583_SEA.csv**, which provides mathematics performance indicators alongside demographic subgroup classifications. These data originate from official education reporting systems used by states and federal education agencies. It allows researchers to compare educational outcomes across jurisdictions with a reasonable level of confidence because the dataset follows standardized reporting procedures. This type of large-scale dataset strengthens the credibility of the analysis because it reflects real-world educational outcomes rather than results from a limited or localized sample.

Rather than focusing on individual students, the study examines aggregated subgroup outcomes reported at the state level. Three student groups form the focus of the analysis: students with disabilities, economically disadvantaged students and English learners. Students with disabilities are those formally identified by school systems as requiring specialized educational support due to learning or developmental challenges. Economically disadvantaged students are identified through eligibility for free or reduced-price lunch programs, which is widely used as a proxy for socioeconomic disadvantage. English learners are students who require additional language support because English is not their primary language.

The key explanatory variable in the study is the demographic classification of students. This variable allows the analysis to determine whether belonging to one of the identified groups is associated with differences in mathematics achievement. The dependent variable is mathematics achievement, measured through standardized mathematics assessment outcomes reported for the 2021-2022 academic year. Specifically, the study uses the percentage of students in each subgroup who achieved proficiency in mathematics. Standardized assessments provide a consistent and widely accepted measure of academic performance, making them suitable for comparisons across states and demographic groups.

To ensure that observed differences in achievement are not incorrectly attributed solely to demographic group membership, the analysis also incorporates several control variables. Grade level is included because academic difficulty naturally increases as students progress through school. State education funding is considered because the level of financial investment in education influences school resources, teacher availability and learning environments. Teacherstudent ratios are included to capture differences in classroom conditions and instructional support. In addition, access to educational resources and support systems is considered, as technologies, learning materials and academic assistance may significantly influence student performance. Controlling for these factors helps isolate the relationship between student background and mathematics achievement.

Data preparation and analysis were conducted using the Python programming environment. Libraries such as Pandas and SciPy were used to clean and organize the dataset, while visualization libraries supported the presentation of findings. The preparation process involved importing the dataset, examining its structure, filtering relevant mathematics indicators and converting percentage values into numerical form suitable for statistical analysis. Records with incomplete or inconsistent information were carefully reviewed, and missing observations were handled using appropriate statistical techniques to maintain the integrity of the dataset. The cleaned data were then organized by state, subgroup and grade level to allow meaningful comparisons.

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Ensuring the validity and reliability of the data was an important part of the methodological process. Construct validity was addressed by confirming that the mathematics proficiency indicators used in the dataset accurately represent student learning outcomes. These indicators are widely used in educational accountability systems and therefore serve as credible measures of academic achievement. Reliability was strengthened by the standardized reporting procedures followed by states. Additional consistency checks were conducted during data preparation to ensure that demographic classifications and performance indicators were reported in a comparable way across jurisdictions.

The analytical process was carried out in several stages. The first stage involved descriptive statistical analysis to understand the general patterns in the data. Mean mathematics performance levels and variations across groups were calculated to provide an initial overview of achievement differences. The second stage involved statistical comparison tests, including t-tests and analysis of variance (ANOVA), which were used to determine whether differences in mathematics performance between groups were statistically significant.

The final stage of the analysis involved regression modeling. Regression analysis was used to examine how demographic group membership relates to mathematics achievement while controlling for grade level, funding levels, teacher-student ratios and resource availability. This approach allows the study to assess the relative influence of these factors simultaneously and provides a clearer understanding of the conditions associated with achievement gaps.

To support interpretation of the findings, visualizations were generated using Python tools such as Matplotlib. Graphical outputs, including bar charts, trend lines and heat maps, were used to illustrate patterns in mathematics achievement across states and demographic groups. Visual analysis complements statistical testing by making complex patterns easier to understand and communicate.

Ethical considerations were carefully observed throughout the study. The research relied exclusively on aggregated public data and did not involve access to individual student records. As a result, the study complies with privacy standards consistent with the Family Educational Rights and Privacy Act (FERPA) and broader research ethics guidelines. Because no identifiable personal information was used, the study posed no risk to students or educational institutions.

4. RESULTS AND DISCUSSION

This section presents the empirical findings of the study and interprets them in relation to the research question, theoretical foundations, and existing literature. The analysis focuses on mathematics achievement disparities during the 2021-2022 academic year among three groups of students: students with disabilities, economically disadvantaged students and English learners. The results are organized into three main parts: demographic achievement gaps, state-level differences, and grade-level trends.

Differences in Mathematics Achievement Across Demographic Groups

The analysis reveals clear and persistent differences in mathematics achievement among the three demographic groups. Across the dataset, students with disabilities consistently recorded the lowest levels of mathematics performance. English learners performed slightly better but still below economically disadvantaged students, while economically disadvantaged students performed somewhat higher than the other two groups but remained below the broader student population. These findings indicate that achievement gaps are not isolated or occasional occurrences; rather, they represent systematic differences linked to structural conditions affecting students' learning environments. Students with disabilities often require differentiated instruction, assistive technologies, and individualized educational plans to effectively engage with mathematical content. When these supports are limited or inconsistently implemented, their academic progress may lag behind their peers. Similarly, English learners face additional challenges related to language comprehension, particularly when mathematical problems rely heavily on textual explanations and complex vocabulary. Economically disadvantaged students may encounter different constraints, including limited access to tutoring, learning materials, and stable study environments outside school.

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Viewed through the lens of social equity, these disparities suggest that equal access to schooling does not automatically translate into equal learning opportunities. Students facing additional barriers require targeted supports in order to reach comparable academic outcomes.

State-Level Variation in Mathematics Achievement

Beyond demographic differences, the analysis also reveals substantial variation across states. The boxplot visualization demonstrates that some states display relatively strong performance, with higher median mathematics scores and wider distributions that suggest stronger educational systems and broader access to learning supports. For instance, States such as Maine & Minnesota reached the highest medians as well as largest ranges indicative of strong systems. In contrast, other states show noticeably lower median scores and tighter performance ranges, indicating more limited outcomes for vulnerable students. Delaware & New Mexico revealed the lowest medians, symptomatic of weak support, as well as relatively high inter-quartile ranges for states like Indiana and Michigan, suggesting some within-state variability.

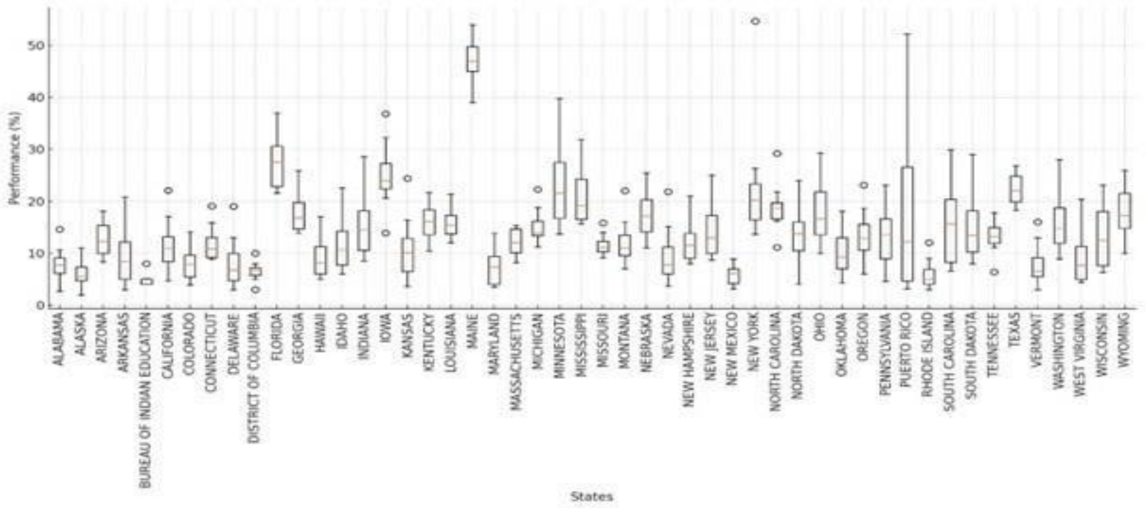

Fig. 1: Mathematics Performance of Students with Disabilities Across U.S. States (2021-2022)

The statistical analysis confirms that these variations are significant. The analysis of variance (ANOVA) produced an F-statistic of 11.43 with a p-value below 0.001, indicating that the differences in mathematics performance across states are unlikely to be due to chance. In practical terms, this means that where students live, and the educational systems that serve them, plays an important role in shaping mathematics outcomes.

These differences likely reflect variations in educational funding, teacher preparation, class size, special education services and access to instructional resources. States with stronger investments in inclusive education, smaller student-teacher ratios and well-developed support programs tend to show narrower achievement gaps. Conversely, states with fewer resources often exhibit wider disparities in mathematics performance.

Comparison Between Overall Student Performance and Students with Disabilities

A closer comparison between the overall student population and students with disabilities further illustrates the magnitude of the achievement gap. Across grade levels and states, the proportion of students achieving mathematics proficiency is consistently higher for the general student population than for students with disabilities.

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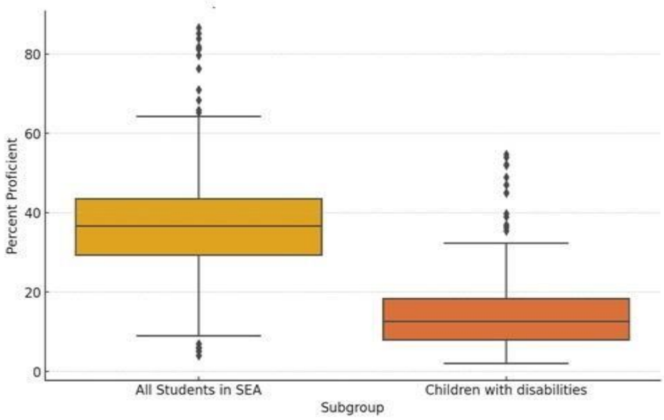

Fig. 2: Mathematics Performance Comparison: All Students vs Students with Disabilities (2021-2022)

The distribution of scores also reveals meaningful differences. While the overall student population displays a wider spread of performance levels including both low and high achievers, students with disabilities tend to cluster at the lower end of the performance distribution. This pattern suggests that many students in this group face similar systemic barriers that limit their academic progress. At the same time, the presence of a small number of high-performing outliers among students with disabilities is an encouraging sign. These cases demonstrate that strong performance is possible when appropriate supports, resources, and instructional strategies are in place. Identifying and learning from these contexts may provide valuable guidance for improving educational outcomes more broadly.

Grade-Level Trends in Mathematics Achievement

Another important objective of the study was to examine how achievement gaps evolve across grade levels. The results indicate that disparities tend to widen as students progress through school. In the early grades (1–3), differences between groups are visible but relatively modest. At this stage, curriculum demands are less complex and many schools provide structured support aimed at building foundational skills. As students transition into middle school (4–8), however, both the conceptual complexity and the language demands of mathematics increase. Here, gaps begin to widen more noticeably, particularly for English learners and economically disadvantaged students.

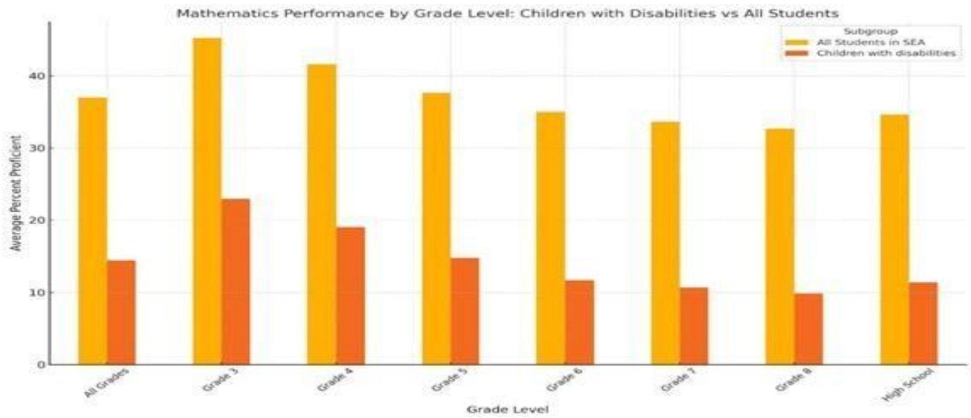

Fig. 3: Mathematics Performance by Grade Level: Students with Disabilities vs All Students (2021-2022) By high school (9–12), performance tends to stabilize, but the earlier gaps largely remain. This pattern suggests that once disparities emerge, they often persist unless targeted interventions are implemented. The findings reinforce the importance of early support and continuous academic assistance throughout students' educational journeys.

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Post-hoc Analysis of Grade-Level Differences

To examine grade-level patterns more rigorously between grade levels for students with disabilities, a post-hoc Tukey Honestly Significant Difference (HSD) test was conducted following the ANOVA analysis. The results show statistically significant differences between several grade levels, particularly when comparing earlier grades with later ones. Many of the confidence intervals associated with these comparisons do not cross zero, indicating meaningful differences in mean mathematics performance.

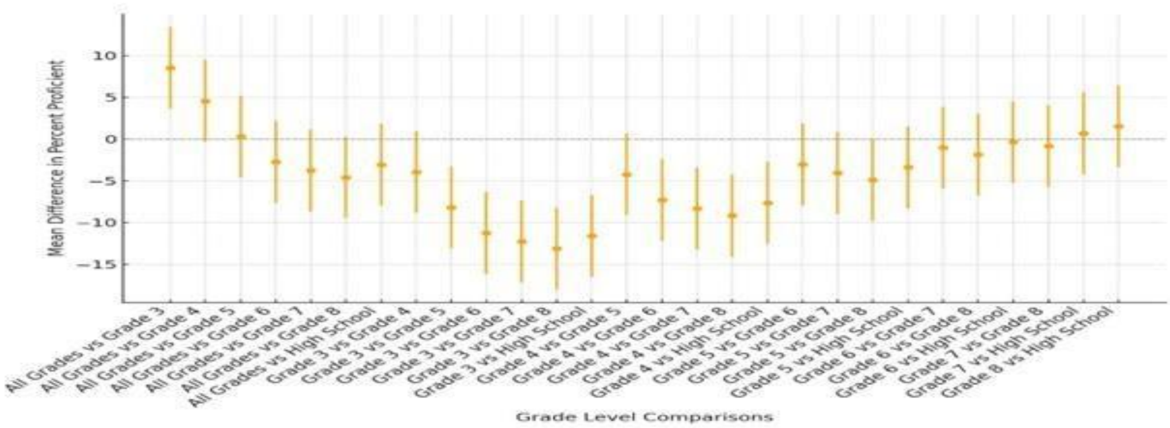

Fig. 4: Post-hoc Tukey HSD: Differences in Mathematics Performance by Grade Level

One of the most striking findings is the sharp decline in proficiency beginning around Grade 5. From this point onward, differences between earlier and later grades become more pronounced. This suggests that the transition into more advanced mathematics marks a critical stage where students who lack sufficient support begin to fall behind more rapidly. Although high school performance appears to stabilize somewhat, it does so at levels lower than those observed in earlier grades.

Regression Analysis of Factors Influencing Mathematics Achievement

The regression analysis provides further insight into the factors associated with mathematics performance, particularly among students with disabilities. Several variables, including access to educational resources, funding levels, and instructional conditions, show measurable relationships with achievement outcomes. Some predictors demonstrate strong statistical significance, while others appear less influential.

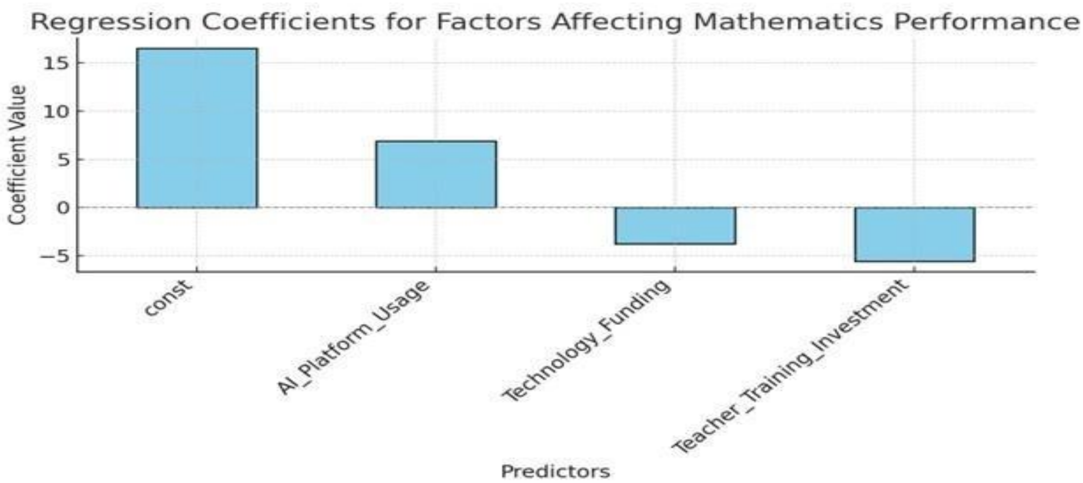

Fig. 4: Regression Coefficients: Factor Affecting Mathematics Performance

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Importantly, the regression results reinforce the broader patterns observed throughout the study. Student outcomes are shaped not only by demographic characteristics but also by the educational contexts in which learning takes place. When students have access to supportive teaching environments, specialized learning tools, and adequate instructional resources, the likelihood of stronger academic performance increases.

Integration with Theoretical Perspectives

The findings of the study align closely with the theoretical frameworks guiding this study. From the perspective of Social Equity Theory, the results demonstrate that unequal access to resources and support systems contributes directly to disparities in educational outcomes. Students who face structural barriers require targeted interventions to achieve comparable academic success. Similarly, the results support key ideas from Constructivist Learning Theory. Learning occurs most effectively when instruction reflects students' individual needs, backgrounds, and learning processes. When educational environments fail to adapt to these differences, achievement gaps are more likely to widen.

In sum, the results present a consistent and compelling picture. Mathematics achievement gaps remain widespread across demographic groups, states and grade levels. The statistical evidence confirms that these differences are substantial and systematic rather than random fluctuations. At the same time, the variation observed across states and educational settings suggests that improvement is achievable. Where schools provide inclusive instructional practices, adequate funding and targeted academic support, achievement gaps tend to be smaller. These findings underscore the importance of sustained policy attention, educational investment and evidencebased interventions aimed at supporting students who face additional learning barriers. Ultimately, reducing mathematics achievement gaps requires a comprehensive approach, one that combines equitable resource allocation, responsive teaching practices and supportive learning environments. When these elements work together, educational systems move closer to providing all students with a genuine opportunity to succeed in mathematics.

5. CONCLUSION AND RECOMMENDATIONS

This study set out to understand how mathematics achievement differs among students with disabilities, economically disadvantaged students, and English learners during the 2021-2022 academic year. This study concludes that closing the mathematics achievement gap requires investments in inclusive education, targeted instructional support, and policies designed to ensure that every student has a fair opportunity to succeed.

Policy Recommendations

One of the clearest lessons from the study is the importance of equitable resource allocation. Educational systems that invest in inclusive teaching practices, specialized support services and well-trained educators tend to produce better outcomes for vulnerable student groups. Governments at both federal and state levels should therefore prioritize funding models that direct additional resources to schools and regions where achievement gaps are most pronounced. Teacher preparation is another critical area. Educators need the skills and confidence to support students with diverse learning needs. This includes training in differentiated instruction, assistive technologies, culturally responsive teaching, and strategies for supporting English learners. When teachers are equipped with the right tools and knowledge, classrooms become more inclusive and effective learning environments.

The results also point to the importance of extending support beyond the early years of schooling. While many educational initiatives focus on elementary education, the findings show that achievement gaps often become larger during middle and high school. Schools should therefore implement sustained support programs such as tutoring initiatives, mentoring schemes, and targeted mathematics interventions throughout students' academic journeys. In addition, technology has strong potential to support learning when used thoughtfully. Adaptive learning systems, assistive technologies and language-support tools can help students overcome barriers and engage more fully with mathematical concepts. However, these tools must be accompanied by proper training and integration into everyday classroom instruction.

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Limitations and Future Research

Although this study provides useful insights, several limitations should be acknowledged. First, the analysis relies on aggregated state-level data rather than individual student records. While this approach allows for broad comparisons across regions, it may mask important differences within states, schools or classrooms. Second, the study uses a cross-sectional design based on a single academic year. As a result, the analysis captures patterns at one point in time rather than tracking how achievement changes over several years. Long-term educational trends and the effects of policy changes may therefore not be fully reflected.

Another limitation relates to differences in data reporting across states. Although efforts were made to ensure consistency and reliability, variations in data collection procedures could introduce some measurement differences. In addition, factors such as school leadership, community support and classroom practices may influence student outcomes but are difficult to capture fully using largescale datasets. Recognizing these limitations does not weaken the study. Instead, it helps place the findings in the proper context and highlights opportunities for deeper future investigations.

Future research may build on this work in several meaningful ways. One important direction is the use of longitudinal studies that follow students over time. Such research would make it possible to understand how achievement gaps develop, whether interventions are effective, and which policies produce lasting improvements. Another valuable avenue involves intersectional analysis. Many students belong to more than one vulnerable group, for example, a student may be both economically disadvantaged and an English learner. Studying how these overlapping challenges interact could provide a more realistic understanding of educational inequality. Finally, further research should also explore the role of emerging technologies in supporting mathematics learning. Artificial intelligence, adaptive tutoring systems and assistive digital tools are becoming more common in education. Understanding when and how these technologies are most effective could help schools implement them more strategically.

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