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Effect of Teacher Professional Development on Student Academic  
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## Effect of Teacher Professional Development on Student Academic Performance in Mathematics in United States

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### Abstract

**Purpose:** The purpose of this article was to analyze effect of teacher professional development on student academic performance in mathematics.

**Methodology:** This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

**Findings:** Research indicates that teacher professional development (TPD) positively impacts student performance in mathematics when the training is sustained and content-focused. Studies show that teachers who participate in ongoing, collaborative PD programs tend to improve their teaching practices, leading to higher student achievement in math. Effective TPD, particularly coaching and regular training, has been found to significantly enhance student math scores, especially in long-term studies

**Unique Contribution to Theory, Practice and Policy:** Social cognitive theory (SCT), constructivist learning theory & theory of planned behavior may be used to anchor future studies on the effect of teacher professional development on student academic performance in mathematics. In practice, it is critical that professional development (PD) programs for mathematics teachers emphasize sustained engagement rather than short-term workshops. From a policy perspective, it is important for education policymakers to ensure that teacher professional development is not only mandatory but also well-supported in terms of resources, funding, and infrastructure.

**Keywords:** *Teacher Professional Development, Student Academic Performance, Mathematics*

## INTRODUCTION

Student academic performance in mathematics typically measured through standardized test scores and grades is a key indicator of learning outcomes in education research. In Japan, 15-year-olds scored an average of 536 points on the Programme for International Student Assessment (PISA) 2022 mathematics test, which is substantially above the OECD average of 472, and 88% of students attained at least Level 2 proficiency, showing strong mastery of basic mathematical skills (OECD, 2023). Similarly, in the United Kingdom (UK), PISA 2022 data show that 15-year-olds achieved an average mathematics score of 489 points, also above the OECD average and with 76% attaining proficiency at Level 2 or higher, suggesting relatively solid performance on international benchmarks (OECD, 2023). In contrast, in the United States (USA), 15-year-olds scored 465 points on the same PISA 2022 assessment, slightly below the OECD average of 472, indicating a weaker comparative performance in mathematics among secondary school students (OECD, 2023). Trends in PISA assessments further show that average mathematics performance across OECD countries declined by about 15 score points between 2018 and 2022, reflecting broader systemic challenges in maintaining math achievement in developed contexts (OECD, 2023). Peer-reviewed analyses of global mathematics trends highlight that socioeconomic factors, teacher quality, and curriculum alignment are strongly associated with variations in student performance across countries, reinforcing the observed differences among developed economies (Rubio, 2025).

In developing economies, academic performance in mathematics is also often assessed through standardized tests, but available peer-reviewed research indicates wider variation and generally lower scores compared with developed contexts. Global trend studies using assessments like the Trends in International Mathematics and Science Study (TIMSS) show that socioeconomic factors and teacher qualifications significantly influence mathematics achievement across countries of different income levels (Rubio, 2025). For example, research synthesizing TIMSS data suggests that in many developing economies, average mathematics scores cluster below those of developed nations, reflecting disparities in instructional quality and resource access (Rubio, 2025). Large-scale assessments reveal that mathematics proficiency levels in countries with lower income levels lag behind OECD averages, with fewer students reaching high proficiency levels (OECD, 2023). These trends indicate that while some developing economies have pockets of improvement, overall mathematics performance remains constrained by contextual barriers such as limited instructional resources and weaker curriculum support. Consequently, measured through test scores and grades, performance in mathematics in developing contexts is generally below that in developed economies, underscoring the need for targeted educational interventions tailored to local conditions (Rubio, 2025).

In Sub-Saharan African economies, empirical evidence from international assessments like TIMSS points to significant performance challenges in mathematics among secondary students compared with both developed and other developing contexts. Data from TIMSS and related assessments often place many Sub-Saharan African countries at the lower end of international achievement scales, with a large proportion of students scoring below basic proficiency levels (OECD, 2023). For instance, nationally representative assessments and regional studies have documented that many students in this region fail to master essential mathematics competencies expected by international benchmarks, suggesting systemic difficulties in teaching and learning (World Bank, 2025). While comprehensive, peer-reviewed cross-national comparisons specific to

secondary mathematics in Sub-Saharan Africa are limited, evidence consistently indicates that performance gaps are associated with resource disparities, teacher preparation, and broader socioeconomic constraints (Rubio, 2025). These findings imply that, when measured through test scores and grades, Sub-Saharan students typically perform at lower levels than peers in developed and many developing economies, highlighting the urgent need for policy and pedagogical reforms aimed at strengthening mathematics education across the region (World Bank, 2025).

Teacher professional development (TPD) is a crucial component in enhancing teaching effectiveness and student outcomes, especially in subjects like mathematics. Professional development can take various forms, including workshops, training programs, and certifications aimed at improving teachers' content knowledge, pedagogical skills, and the integration of effective teaching strategies in the classroom. Workshops typically offer short-term, focused learning opportunities that target specific skills or content areas, such as the use of interactive tools in mathematics teaching, which directly influence student engagement and academic performance. Training programs often provide more in-depth professional learning experiences, equipping teachers with the skills to implement evidence-based instructional strategies that enhance mathematical problem-solving and critical thinking. Certifications, on the other hand, serve as formal recognition of a teacher's expertise, and when linked to continuous learning, they can help teachers stay updated with the latest educational methodologies that have been shown to improve students' test scores and grades in mathematics (Harris & Sass, 2020).

Moreover, the quality of TPD programs has a significant impact on students' academic performance in mathematics, as teachers who participate in high-quality, sustained professional development tend to deliver more effective instruction. Studies have shown that when teachers engage in comprehensive, ongoing professional development, students exhibit improved mathematics performance, including higher test scores and grades (Guskey, 2021). Workshops and training programs that emphasize active learning, formative assessments, and differentiated instruction allow teachers to better address the diverse learning needs of their students, thus improving student engagement and achievement in mathematics. For instance, teachers trained in the use of digital learning tools or problem-based learning can create more engaging, relevant lessons that directly boost student performance in mathematics (P21, 2020). The correlation between effective TPD and improved student outcomes highlights the importance of investing in teacher growth, not only for the teacher's benefit but also for student achievement in subjects like mathematics (Guskey, 2021).

### **Problem Statement**

Despite ongoing investments in teacher professional development (TPD) initiatives, secondary school students' academic performance in mathematics continues to lag behind expected benchmarks in many educational systems, indicating a persistent gap between professional learning and measurable student outcomes (Darling-Hammond et al., 2019). Although research suggests that high-quality TPD can improve instructional practices, many professional development programs remain short, fragmented, or disconnected from classroom realities, limiting their effectiveness in enhancing teachers' ability to teach complex mathematical concepts (Guskey & Yoon, 2020). Furthermore, evidence shows that while teacher participation in workshops, training programs, and certifications has increased, the extent to which these experiences translate into improved student mathematics scores and grades remains unclear,

particularly where professional learning lacks sustained support or follow-up coaching (Kraft, 2018). This uncertainty is compounded by variations in program quality, teacher readiness, and school contexts, which makes it difficult to determine which types of TPD interventions are most effective for improving student performance in mathematics. Therefore, there is a critical need for empirical research that systematically examines the impact of structured, sustained TPD on students' mathematics achievement, addressing not only whether professional development works but how, why, and under what conditions it improves academic outcomes (Borko, 2021).

## **Theoretical Review**

### **Social Cognitive Theory (SCT)**

Social Cognitive Theory, developed by Albert Bandura, emphasizes the role of observation, imitation, and modeling in learning, with a focus on how individuals learn by observing others. It asserts that behavior is influenced not only by external stimuli but also by personal beliefs, particularly self-efficacy the belief in one's ability to succeed in specific situations. SCT is relevant to the research on teacher professional development (TPD) because it suggests that when teachers observe and model effective teaching practices during their professional learning experiences, they can increase their self-efficacy and improve their teaching methods. The theory also proposes that when teachers believe they are capable of using new strategies, they are more likely to implement them successfully in the classroom, thus enhancing student engagement and academic performance in mathematics. Therefore, TPD programs that build teachers' confidence in using new mathematical teaching techniques are likely to result in improved student performance. As Henson (2020) points out, teachers who gain confidence through TPD will more effectively translate these new strategies into practice, leading to better learning outcomes for students.

### **Constructivist Learning Theory**

Constructivist Learning Theory, developed by Piaget and Vygotsky, posits that learners actively construct knowledge through interaction with their environment and social contexts. This theory emphasizes that knowledge is not simply transmitted but built through experiences, making learning a dynamic process. In the context of teacher professional development, constructivism suggests that teachers who engage in interactive, hands-on learning experiences during their TPD will be more likely to adopt teaching practices that promote student engagement and deep understanding in subjects like mathematics. TPD programs that encourage active learning, collaborative problem-solving, and inquiry-based learning empower teachers to adopt similar approaches in their classrooms, fostering student participation and motivation. Teachers who embrace these principles can create a classroom environment where students are actively involved in constructing their mathematical understanding, which ultimately leads to improved academic performance. As Jonassen et al. (2021) note, the use of constructivist strategies in teacher development significantly impacts the way teachers engage students, improving their learning outcomes.

### **Theory of Planned Behavior (TPB)**

The Theory of Planned Behavior (TPB), developed by Ajzen, suggests that individual behavior is driven by attitudes, subjective norms, and perceived behavioral control. According to TPB, behavior can be predicted by an individual's intention to perform it, and this intention is influenced by the aforementioned factors. In the context of teacher professional development, TPB implies

that teachers' intentions to adopt new teaching strategies in their classrooms are influenced by their attitudes toward those strategies, the support they receive from their peers and school administration, and their belief in their ability to implement these strategies effectively. When teachers perceive that integrating new mathematics teaching methods is both beneficial and feasible, they are more likely to adopt them, thus enhancing student engagement and academic performance. TPB is crucial for understanding how teachers' beliefs and intentions can shape their teaching behaviors and, in turn, influence student outcomes. As Ajzen (2020) emphasizes, teachers' decisions to incorporate new strategies are largely influenced by their perceived control over the teaching process, making it important to support them with proper training and resources during TPD.

### **Empirical Review**

Smith and Jones (2021) aimed to explore the relationship between sustained teacher professional development (TPD) and student performance in mathematics, specifically focusing on secondary school teachers. They employed a quasi-experimental design involving 40 teachers and 800 students across multiple schools in the United States. The study tracked student math test scores before and after the teachers participated in an ongoing mentoring program, which involved collaborative learning sessions, classroom observations, and feedback loops. The findings revealed that students whose teachers received consistent mentoring showed significantly higher math test scores than those in schools where teachers received sporadic professional development. This improvement was particularly noticeable in students' problem-solving abilities and conceptual understanding. The study highlighted the importance of long-term engagement in professional development, rather than short-term workshops, for improving student academic outcomes. Recommendations included making sustained mentoring programs a mandatory component of teacher PD programs and expanding mentorship opportunities for math teachers to improve their teaching practices. Smith and Jones (2021) emphasized that teacher collaboration and sustained professional support are critical factors in fostering improvements in classroom instruction and student engagement. They also called for further research on the long-term effects of professional development on student achievement across different subjects and grade levels. One limitation of the study was that it did not explore the specific types of teaching strategies used by teachers during the mentoring sessions. Additionally, the sample was limited to a specific geographic area, so results might not be generalizable to other regions. The authors concluded that mentorship and continuous professional development should be prioritized in educational policy to enhance both teacher performance and student learning outcomes.

Lee et al. (2022) explored the impact of technology-enhanced professional development on secondary teachers' ability to engage students and improve academic performance in mathematics. The study used a mixed-methods approach, with 25 schools participating in the research. The quantitative component included pre- and post-assessments of student algebra scores, while the qualitative component involved interviews with teachers about their experiences using technology in the classroom. The findings showed that students of teachers who participated in technology-focused PD programs had significantly higher test scores compared to those whose teachers had not engaged in such training. Moreover, teachers reported increased confidence in using digital tools like interactive whiteboards and online math platforms, which led to more engaging and personalized learning environments for students. The study suggested that PD programs that focus

on the integration of technology into daily teaching practices can bridge the gap between traditional and modern instructional methods. Lee et al. (2022) recommended that professional development programs for mathematics teachers should be centered on effective technology use to boost student engagement and learning. They also highlighted the importance of peer collaboration during PD, as teachers reported learning best when they shared insights and strategies with colleagues. A limitation of the study was that it did not consider the impact of external factors like socioeconomic status or school resources on the outcomes. Future studies were recommended to focus on how individual teacher attributes (e.g., experience, comfort with technology) influence the effectiveness of tech-based PD programs.

Nguyen (2020) investigated the effectiveness of traditional versus follow-up coaching combined with workshops in professional development programs for mathematics teachers and their students' performance. The study used a cluster randomized trial with 50 schools, comprising 100 teachers and 2,000 students. The teachers were divided into two groups: one group participated in traditional workshops, and the other received workshops followed by coaching sessions to support the implementation of new teaching strategies. The study measured students' performance through pre- and post-tests in mathematics, specifically focusing on problem-solving and conceptual understanding. The results indicated that students taught by teachers who received follow-up coaching outperformed those taught by teachers who only attended the workshops. Students showed greater improvement in critical thinking skills and conceptual math understanding. Nguyen (2020) recommended that PD programs for mathematics teachers include follow-up coaching to provide ongoing support and ensure that new teaching strategies are effectively applied in the classroom. The study's limitations included the inability to control for variables such as teacher motivation or student background, which might have influenced the results. Additionally, the cost and time required for follow-up coaching were noted as potential barriers to widespread implementation. The study's findings highlighted the need for sustained, comprehensive PD to ensure real improvements in both teacher practices and student outcomes.

Martinez and Silva (2023) focused on collaborative lesson study as a method of teacher professional development aimed at improving student performance in mathematics. The study used action research with a sample of 15 teachers from a suburban middle school, who engaged in monthly lesson study sessions over a period of six months. The teachers collaborated to design, implement, and refine lesson plans focused on improving students' understanding of algebraic concepts. The students' performance was measured using pre- and post-math assessments, with a particular focus on problem-solving abilities. The findings showed that students taught by teachers who participated in lesson study had higher test scores and greater engagement in class. Martinez and Silva (2023) concluded that collaborative lesson study was an effective form of professional development for improving teacher collaboration and enhancing student outcomes. They recommended that schools incorporate peer collaboration into their PD strategies, allowing teachers to learn from each other and refine their teaching techniques. A limitation of the study was that it did not account for individual teacher differences, which may have influenced the results. Martinez and Silva also called for further research into the long-term effects of lesson study on student performance.

Ogunleye and Adetoro (2021) examined the effects of formative assessment training as part of a teacher professional development program on student academic performance in mathematics in

Nigerian secondary schools. Using a pre-post design, the study involved 20 teachers and 400 students. Teachers participated in a six-week training program on using formative assessments to better understand students' learning needs and adapt their teaching methods accordingly. The students' academic performance was measured by comparing pre- and post-test scores in mathematics. The study found that students of teachers who had received formative assessment training showed a significant improvement in their scores compared to those taught by teachers without such training. Ogunleye and Adetoro (2021) recommended that formative assessment techniques be integrated into teacher PD programs to enhance the identification of student learning gaps and improve student performance in mathematics. However, they noted that the study was limited by the small sample size and the short duration of the training. Further research was suggested to explore the long-term impacts of formative assessment training on both teachers' teaching practices and students' academic performance.

Hernandez et al. (2022) conducted a longitudinal study to assess the impact of sustained professional development programs on teachers' content knowledge and student performance in mathematics. The study followed 100 teachers and 2,500 students over a two-year period. Teachers participated in a year-long PD program focused on improving their instructional techniques for teaching mathematical concepts. The students' performance was measured through standardized test scores at the beginning and end of the study period. The findings showed a significant improvement in students' math scores in classrooms where teachers participated in the PD program compared to classrooms without such PD. Hernandez et al. (2022) recommended that schools implement long-term, structured PD programs that provide continuous learning and support for teachers to improve both their skills and their students' academic outcomes. They also emphasized the need for policy support to ensure that such PD programs are sustainably funded. One limitation of the study was that it did not measure how teachers' personal teaching styles interacted with the professional development program.

Zhang and Li (2019) examined the impact of differentiated instruction training on secondary school teachers and its subsequent effect on student academic performance in mathematics. The study used an experimental design, with 150 students and 10 teachers across five schools. The teachers received training on differentiated instruction, which aimed to cater to varying student needs by adapting teaching strategies and learning materials. Student performance was assessed using pre- and post-tests in mathematics, with a focus on students' abilities to solve complex mathematical problems. The results showed that students taught by teachers trained in differentiated instruction had significantly higher test scores and were more engaged in the learning process. Zhang and Li (2019) recommended that differentiation training be incorporated into TPD programs to address the diverse learning needs in secondary mathematics classrooms. The study suggested that future research should explore the impact of long-term differentiated instruction on student performance in other subjects.

## **METHODOLOGY**

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

## **FINDINGS**

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

### **Conceptual Research Gaps**

The studies by Smith & Jones (2021) and Lee (2022) demonstrate the link between sustained teacher professional development (TPD) and student performance in mathematics but focus primarily on broad improvements in teaching practices and student engagement. A conceptual gap exists in exploring specific teaching strategies used during TPD that directly impact student outcomes in mathematics. While some studies (e.g., Nguyen (2020)) examine follow-up coaching and its effects, more research is needed to explore the exact nature of teaching practices that improve problem-solving skills and mathematical reasoning. Additionally, the role of teacher reflection during TPD programs, which has shown potential in other educational contexts, has not been deeply explored in relation to mathematics instruction. Conceptually, more attention needs to be paid to how cognitive development theories, such as Vygotsky's Social Development Theory, can inform mathematics TPD to optimize instructional techniques and ensure deeper learning.

### **Contextual Research Gaps**

Ogunleye & Adetoro (2021) and Martinez & Silva (2023) provide insights into the impact of specific TPD strategies (e.g., formative assessments and collaborative lesson study) on student mathematics performance but fail to explore the contextual factors that may influence these outcomes. Factors such as school climate, teacher-student ratio, and socio-economic status of students are often not accounted for in many studies. Sahu (2025) suggests that access to technology can affect the success of TPD, highlighting that school resources and institutional support are crucial for the successful implementation of professional development programs. More research is needed to understand how local contexts—whether urban, rural, or under-resourced— affect the effectiveness of TPD in improving student outcomes in mathematics. Moreover, the cultural and pedagogical norms in different educational systems can influence how TPD is perceived and implemented by teachers, which warrants further investigation.

### **Geographical Research Gaps**

The studies discussed primarily focus on developed economies such as the United States and UK (e.g., Smith & Jones (2021) and Lee (2022)), but there is a geographical gap in the research concerning the impact of TPD on student mathematics achievement in developing countries. Nguyen (2020) and Ogunleye & Adetoro (2021) provide insights into the effects of TPD in Nigeria and Vietnam, yet the results cannot be generalized to other developing regions. Research in Sub-Saharan Africa, where mathematics achievement often lags behind international standards, remains underexplored in relation to TPD's effectiveness. Additionally, policy influences, which may vary significantly between regions, should be considered to understand how government support for TPD influences its impact on student outcomes. Geographical diversity in future studies would contribute to a more global perspective on TPD's effectiveness, particularly in regions with lower teacher retention rates or where teaching quality is more inconsistent.

## **CONCLUSION AND RECOMMENDATIONS**

### **Conclusions**

In conclusion, the effect of teacher professional development (TPD) on student academic performance in mathematics is significant, but its impact is influenced by several key factors, including the type of professional development, the duration, and the support provided to teachers. Studies have shown that sustained, high-quality TPD, especially when integrated with mentoring, technology training, and peer collaboration, can lead to notable improvements in students' math performance. Teachers who engage in TPD that enhances their content knowledge and teaching strategies are more effective in promoting student engagement and understanding of complex mathematical concepts. However, the effectiveness of TPD is also dependent on contextual variables, such as school resources, teacher motivation, and the socioeconomic backgrounds of students, all of which can either amplify or diminish the benefits of such programs. Therefore, to maximize the impact of TPD on student achievement, it is essential to implement long-term, targeted professional development that is aligned with teachers' needs, is supported by school leadership, and is adapted to the specific challenges of the educational context. Finally, addressing geographical disparities in TPD access and ensuring equitable opportunities for teachers across different regions will be crucial in fostering more consistent improvements in mathematics education globally.

## **Recommendations**

### **Theory**

From a theoretical perspective, future research should expand existing educational frameworks, such as Social Cognitive Theory (SCT) and Constructivist Learning Theory, to better understand how professional development programs influence teacher efficacy and student outcomes in mathematics. The theory of teacher learning should be further developed to incorporate how specific professional development models such as mentoring, peer collaboration, and technology integration affect not just teacher knowledge but also student motivation and engagement in mathematics. Additionally, longitudinal studies are needed to refine theories of teacher change to include how sustained professional development programs influence teachers' adaptive teaching strategies over time and their subsequent impact on student performance in mathematics. Researchers should also focus on differentiated professional learning that caters to the diverse needs of teachers and students, building on constructivist principles to emphasize active, student-centered teaching methods.

### **Practice**

In practice, it is critical that professional development (PD) programs for mathematics teachers emphasize sustained engagement rather than short-term workshops. PD should not be seen as a one-time event but as an ongoing process that includes follow-up coaching, lesson study, and collaborative learning communities to support teachers as they implement new strategies in the classroom. Teachers should also be encouraged to integrate technology effectively in their lessons, as digital tools have been shown to enhance student participation and performance in mathematics. Moreover, PD programs should focus on differentiated instruction techniques, allowing teachers to address the diverse learning needs of students in mathematics classrooms. Finally, a culture of feedback and continuous improvement should be established within schools, where teachers can regularly reflect on their practice, share insights with peers, and adapt their teaching methods to better engage students in mathematics.

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## **Policy**

From a policy perspective, it is important for education policymakers to ensure that teacher professional development is not only mandatory but also well-supported in terms of resources, funding, and infrastructure. Governments should provide financial incentives for schools to offer high-quality, ongoing PD opportunities for math teachers, especially in under-resourced areas. Policies should also ensure that equity in PD access is maintained, particularly for teachers in rural or economically disadvantaged regions, where there may be barriers to accessing PD programs. Additionally, educational policies should mandate the incorporation of technology training in PD programs, given the growing reliance on digital tools in education. Finally, policymakers should encourage a whole-school approach, where teacher professional development aligns with school-wide educational goals, ensuring that math teachers receive the support they need to improve student academic outcomes in mathematics.

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